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ABSTRACT

A seventh-grade class took tests in block design problems to determine the importance of three techniques of programed instruction. The techniques under consideration were sequencing, cueing, and individual response. The research design looked at the performance of three ability levels (high, medium, and low) divided by sex over five program treatments (control, program, group paced, cues removed, and sequence mixed). Results showed that the high ability group performed equally well regardless of program techniques. Sequencing was significant for the middle and low ability levels, and cueing was significant for the low ability level. It was concluded that given a seventh-grade learning task, high ability level seventh graders have little need for program-like sequencing, cueing, and individual response. But at the lower ability levels, there is a strong need for the full employment of such techniques. The greatest need is for sequencing, and the second greatest is for cueing or more detailed guidance. (JK)

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By

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A Dissertation
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Of Doctor of Philosophy in Education

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INTRODUCTION

This study is centered about one aspect of the importance of individual differences in relation to some of the research designs on the techniques of programmed instruction. It concerns the relationship of cognitive capacity to the effectiveness of three techniques of programmed instruction that are frequent subjects for research. For the purposes of this study cognitive capacity is defined as the individual ability to quickly comprehend a concept or whole idea through an efficient mental organization of the given sub-parts of the concept. Such an ability is most probably made up of several dynamic variables. However, for simplicity's sake, the functional effect of this ability in this research design is considered cognitive capacity. If such a capacity does interrelate with the techniques of sequencing, cueing and responding, then any research concerning programming techniques that does not refine its use of treatment averages to account for this factor could give a variety of divergent results.

As a matter of fact, much divergent opinion has been expressed about the value of response, cueing and sequencing. Therefore, if it can be established that some factor such as cognitive capacity interacts with the effects of sequencing, cueing and responding techniques, this knowledge may help clarify the problem. Also, more efficient learning systems could be tailored to allow the best gains possible for the learner at his particular stage of cognitive development in

a given kind of learning situation.

The writer has used a research design which had three main foci. The first focus called for a simple experiment which allows participation of the full achievement range in a given grade level while causing a minimum amount of disruption of regular classes. The second focus called for an experiment that could be easily replicated. And the third was the need for an experiment that is free of cultural limitations.

The first focus was based on some uneasiness concerning the ability of experimenters to get truly representative samples of a broad range of learners. As the related literature which follows shows, the subjects selected were often academic achievers only. The subjects were usually college students and few low academic achievers are found among such subjects. The reason for the second focus was simply the hope that any findings from this experiment can be easily verified, repudiated, or modified through replication. Thus, in creating a simple design, the thinking of Gage is followed in regard to the divergence of findings in educational research:

. . . take the same path that the more mature sciences had already followed: If variables at one level of phenomena do not exhibit lawfulness, break them down. Chemistry, physics and biology had, in a sense, made progress through making finer and finer analysis of the phenomena and events they dealt with.¹

The last focus was rather specific for educational technology. By definition, specialists in this field are committed to work for

¹Nathaniel L. Gage, "An Analytical Approach to Research on Instructional Methods," Phi Delta Kappan, Vol. 49, No. 10, 1968, p. 602.

the catholicity expected of a technology. They can not simply attempt to translate arbitrary culture-bound rules from one language to another. Educational technology must consider man the learner as a highly individualistic organism. The more that we can refine our knowledge about his individual differences the more we will know about him as a learner.

To accomplish the first focus a program was developed using seventh grade subjects. After testing and retesting on seventh graders a sequence of seven frames was selected to accomplish the learning objective--a relatively quick solution of a criterion block problem. The materials were blocks similar to those blocks used in the aptitude tests of Kohs and Wechsler.²

The program or its variations can be administered in approximately ten to fifteen minutes and the number of subjects processed at any time is limited only by the carrels, materials, timers and observers available.

Although, considering the second focus, multiple analysis of variance will be used to test for significance, the initial design (five treatments by three levels of aptitude by sex) is open to several statistical tests. The materials are not complex nor are they prohibitively expensive. Neither is the equipment. Hopefully, for replication purposes, the minimum disruption worked for in the first focus will aid in getting the permission of school authorities

² Samuel C. Kohs, Intelligence Measurement (New York: Macmillan, 1923); and David Wechsler, The Measurement of Adult Intelligence, 3rd ed. (Baltimore: William E. Wilkins, 1944.)

to use the full range of achievement in appropriate grades in their schools.

Lastly, there was an attempt to provide an experiment that will span both cultural differences and subcultural differences to plumb at basic learning abilities rather than those that may be more a measure of subcultural verbal sophistication. Educational technology must go beyond research that is keyed to the high verbal literacy of successful academic achievers from affluent middle class American society.

Educational technology can help the undereducated throughout the world to catch up if it can establish universally efficient learning techniques. The need for a study which has universal application prompted the experimenter to choose non-verbal frames and culturally-free block design problems.

Cultural and Subcultural Differences

There are some indications in the literature which follows that our present learning theories fit better the high academic achiever and that because of this much of the learning potential of the academic non-achiever has been ignored. More universally applicable information on learning is needed not only for the sake of the learners in the United States but for all learners, especially the undereducated and the underachiever.

The data from researchers using the block designs tests of Kohs or Wechsler have uncovered strong evidence that block design tests stand up extremely well across different cultures and

sub-cultures.³

In asking whether the poor nations can afford the educational approach of the West, Mr. Zimmer points out that a network of traditional non-verbal communication has been in operation for over 3500 years in India and that it embraces every aspect of life.⁴

In the United States, Nicholas Anastasiow⁵ believes that probably nothing on today's educational scene has created more attention and controversy than Arthur R. Jensen's argument that genetic factors are strongly implicated in the average Negro-white intelligence

³ Samuel Kohs, op. cit.

David Wechsler, op. cit., pp. 61-92.

C. J. Adcock, et al. "An Analysis of Maori Scores on the Wechsler-Bellevue," Australian Journal of Psychology, Vol. 6 (1954) pp. 16-29.

Grace T. Altus, "WISC Pattern of a Selective Sample of Bilingual School Children," Journal of Genetic Psychology, Vol. 83, (1953) pp. 241-48.

Robert J. Howell, Lavon Evans, and Lester N. Downing, "A Comparison of Test Scores for The 16-17 Year Age Group of Navahoe Indians With Standardized Norms For the Wechsler Adult Intelligence Scale," Journal of Social Psychology, Vol. 47 (1958), pp. 355-59.

Pierre Romier, "Le Recrutment de la Main D'oeuvre Nord Africaine," Bulletin du Centre d'Etudes Recherches Psychotechniques, Vol. 7, (1958) 221-27.

Arthur Sullivan, "Measurement of Intelligence in Different Environments," Maritime Psychological Association Bulletin, Vol. 6, (1957) pp. 18-23.

⁴ Fred Zimmer, "Can The Poor Nations Afford the West?" A.V. Communications Guide, Vol. 17, No. 1, 1969, pp. 84-94.

⁵ Nicholas Anastasiow, "Educational Relevance and Jensen's Conclusions," Phi Delta Kappan, Vol. 51, No. 1, 1969, pp. 32-35.

difference.⁶ In reviewing the counter arguments, Anastasiow⁷ lines up impressive research to show that: "What is taught by the lower-class mother appears to be nonverbal cognitive systems which may reflect intellectual functionings that our typical intelligence tests do not measure." He⁸ further proposes that: "Our teaching procedures must come to match the competencies and the level of development the child brings with the requirements of the task to be learned."

Ralph H. Hines⁹ has written an excellent and well annotated sociological study which delineates the disadvantageous situation of the culturally deprived in regard to a poorly developed repertoire of conventional middle class learning skills. He feels that there is special hope for ameliorating this cultural deprivation through the potential offered in programmed teaching.

Eunice Newton has coined the powerful phrase of "verbal destitution" to describe this subcultural difference.¹⁰

⁶ Arthur R. Jensen, "How Much Can We Boost I.Q. and Scholastic Achievement?" Harvard Educational Review, Vol. 39, No. 1, 1969, pp. 1-123.

⁷ Anastasiow, op. cit., p. 34.

⁸ Ibid., p. 35.

⁹ Ralph H. Hines, "Automation and Culturally Deprived Children," Programmed Teaching, ed. by Joseph S. Romcek, Philosophical Library, New York, 1965.

¹⁰ Eunice S. Newton, "Verbal Destitution: The Pivotal Barrier to Learning," Journal of Negro Education, Vol. 29, No. 3, 1960, pp. 497-499.

Learning and aptitude testing in our culture has been involved with and dependent on a preponderant amount of verbalization. In general, extant learning theories that did not derive from verbal dependent research seem to have derived from animal learning or an animal level of learning. It seems high time that we try to find out as much as we can about human learning in non-verbal modes so that we can discern individual differences if and where they apply.

For instance, Spellmann,¹¹ familiar with the fact that young children preferred to match things in terms of color rather than form but that between the ages of four and seven years they shift to a preference for form, set up an experiment to study the timing of this shift. His research found that Negro school children shifted from color to form more slowly than did Anglo and Indian school children.

Certainly the nature-nurture argument seems like a pitiful waste of time as long as we use so-called intelligence tests that

¹¹Charles Mac Spellmann, The Shift from Color to Form Preference in Young Children of Different Ethnic Backgrounds, Texas University, Austin, 1968.

depend so heavily on the very nurture (verbalization and concept enrichment) that is denied to many of the poorer achievers. The scales seem so weighted that little in the way of reliable results can be obtained. A much earlier and very lucid reference to this problem was made by Davis in 1951.¹²

Obviously, the effects of cultural differences in the dynamics of learning must be neutralized before much can be determined about the influence of some of the other individual differences.

Individual Differences

It is unfortunate that so much research in programmed instruction seems to accept the artifact of an average student. Today's technology, correctly used, can overcome almost all the past educational constraints that forced the practical acceptance of aiming at the middle in any given learning situation involving several learners.

Gotkin points out that while programmed instruction made an enormous stride toward individualizing instruction in breaking the traditional lock step of classroom procedure, ". . . there is little evidence that programs thus far written for classroom use really individualize classroom instruction."¹³

Wilbur Schramm in discussing research on programmed instruction points out ". . . not a great deal has been done yet

¹²Allison Davis, "Socio-economic Influence on Learning," Phi Delta Kappan, Vol. 32, No. 5, 1951, pp. 253-56.

¹³Lassar G. Gotkin, "Programed Instruction in the Schools: Individual Differences, the Teacher, and Programing Styles," Programs, Teachers, and Machines, Des Plaines, Illinois: Bantam, 1965, p. 170.

to understand how to modify programs for different levels of ability."¹⁴

It has been aptly said that research (or, in this case, the programs on which research is based) that applies to some generalized "average" student in fact applies to no one. The problem of individual differences is not new in education by any means. There has been a concern for such variances in intellectual performances for over one hundred years.

Guilford points out in his discussion on the historical background of this concern that as early as 1870 F. Galton remarked on the extensiveness of individual differences.¹⁵ In 1911 Edward L. Thorndike published a monograph on Individuality that addressed itself to individual differences. He emphatically pointed out the need to consider these differences in any given learning situation.¹⁶

Much excellent work has been done for those with the more discernible physical differences such as blindness, deafness and retar-

¹⁴ Wilbur Schramm, The Research on Programed Instruction, Washington, D. C.: U. S. Government Printing Office, 1964, p. 14.

¹⁵ Joy P. Guilford, The Nature of Human Intelligence, (New York: McGraw-Hill, 1967) p. 2. (F. Galton, Hereditary Genius: An Inquiry Into Its Laws and Consequences, New York: Macmillan, 1869.)

¹⁶ Edward L. Thorndike, Individuality, Boston, Massachusetts: Houghton-Mifflin Company, 1911.

dition. And within constraints such as large classes and lock-step schedules that obtain in most of the traditional normal range learning situations, the sensitivity to individual differences has been exemplary and fruitful. However, educational technology has the special potential to change the old constraints and put new dimensions into the consideration of individual differences. If we accept Stolurow's¹⁷ proposition that we can freeze the educational process in order to examine it thoroughly we can imagine a careful study of the components of any given program to see where it can be adapted and validated against individual differences to an extent limited only by the allowable cost of the effort.

The fact remains, however, that programmed instruction after its initial breakthrough of self-pacing has been slow if not insensitive to further exploitation of this breakthrough in the problem of individual differences. In another discussion Gotkin says: "Although a vast amount of programing and research has been accomplished over the past five years, the issue of individual differences, unfortunately, has received little attention." He offers as the probable cause for this the fact that programmed instruction evolved from operant conditioning research and is oriented toward an approach to education based on behavioral psychology.

Programs have contributed more to the individualizing of

¹⁷Lawrence M. Stolurow, "Teaching Machines and Programmed Instruction," The American Behavioral Scientist, Vol. VI, No. 3, 1962, pp. 43-5.

instruction rather than providing for individual differences. That is allowing a learner to proceed at his own pace, individualizes the instruction, but does not necessarily allow for the individual differences that contribute to the varying rates of pacing.¹⁸

Gotkin further states:

... the style of the learner needs to be matched with the teaching style of the programs. Individual differences in pretest knowledge and cognitive capacity dictate entirely different programs for different students in the case of most subject matters.¹⁹

Snow and Salomon²⁰ point out that the statistical techniques borrowed from the animal laboratory and the agricultural experiment station may not be as neatly applicable to research designs about human learning. They argue that treatment averages were more meaningful for these animal and agricultural studies because deviations from the average are small in such groups and because most background variables can be assumed to be constant. However, the highly mobile and individualistic character of humans tends to make any group of them highly varied and the random division of a heterogeneous group does not destroy its heterogeneity. Treatment averages may hide more than they reveal.

¹⁸ Lassar G. Gotkin, "Cognitive Development and the Issue of Individual Differences," Programed Instruction, Vol. 4, No. 1, 1964, p. 3.

¹⁹ Ibid., p. 4.

²⁰ Richard E. Snow and Gavriel Salomon, "Aptitudes and Instructional Media" A. V. Communications Review, Vol. 16, No. 4, 1968.

It is like comparing tigators or applanges. Some improvement is brought to the situation if individuals are first separated into tigers and alligators or apples and oranges so that average comparisons can be meaningfully interpreted within these subgroups.²¹

Therefore the thrust of this research is to show that individual differences, gathered into homogeneous groupings, are very much related to the effects of sequencing, cueing, and responding in programmed instruction.

While the design of this study is far from offering the ultimate in defining homogeneous groups, the divisions do offer discrete segments and some degree of approaching this kind of grouping.

Sequencing

It is not accidental that there is much more research on the effects of sequencing than on the effects of cueing or response involvement. The ordering or disordering of sequence is much easier to specify than is the apparent right amount or the inappropriate amount of cueing. This would also be so for response involvement.

Perhaps in the area of sequencing more than any other, the issue has been confounded by the narrow scope of behavioral theory. Logically, the stimulus-reward paradigm should offer some optimal sequencing pattern for all learners in any given learning task. Basic to the behavioral approach propounded by Skinner was the notion that through empirical feedback from learners to programmer,

²¹Ibid., p. 343.

there can be developed an optimal learning sequence.²² And yet the divergence of research findings, if nothing else, seems to decimate this theory.

Gavurin and Donahue²³ while finding significant efficiency (fewer errors and fewer trials) for a logical sequence over a random sequence for twenty-nine items on psychology, found no significant difference in a test of retention one month later. Levin and Baker²⁴ found no significant differences on acquisition, retention or transfer between those who studied an ordered and those who studied a randomized sixty frames of geometry at the second grade level. K. V. Roe²⁵ found no significant difference on a short program of 71 frames on elementary probability between two groups of freshmen, one using a logical sequence and the other using a random sequence. Zuckerman, Marshal and Groesberg²⁶ found no significant

²²Arthur A. Lumsdaine, "Educational Technology, Programmed Learning and Instructional Science," Theories of Learning and Instruction Chicago: National Society for the Study of Education, 1964, pp. 371-402.

²³Edward L. Gavurin and Virginia M. Donahue, "Logical Sequence and Random Sequence Teaching Machine Programs," Automated Teaching Bulletin, Vol. 1, No. 4, 1961, pp. 3-9.

²⁴Gerald R. Levin and Bruce L. Baker, "Item Scrambling In A Self-Instructional Program," Journal of Educational Psychology Vol. 54, No. 3, 1963, pp. 138-143.

²⁵Kiki V. Roe, "Scrambled Vs. Ordered Sequence in Auto-Instructional Programs," Journal of Educational Psychology, Vol. 53, No. 2, 1962, pp. 101-104.

²⁶Carl B. Zuckerman, George R. Marshal, and Sanford Groesberg, Research in the Automation of Teaching, Port Washington, N. Y.: U. S. Naval Training Device Center, 1961.

differences between groups studying an ordered and a random program of sixty items on electricity.

On the other hand, Arnold Roe²⁷ using 189 freshman engineering students and a linear program of 107 frames in probability concepts found that the logical sequence of the program resulted in more learning than the random sequence.

In an early study, Miller²⁸ using a ninety-eight frame program in mathematics which was presented in logical and random sequence to middle-track seventh graders found exactly the same mean scores on the criterion test of fifty items. However the high pre-test scores indicated a strong repertoire of experience or familiarity with the content of the program. Random ordering under such conditions does not seem to be difficult for subjects to realign and overcome.

These early studies were criticized for inappropriate combinations of program subject matter and learners, poor measures, poor programs, length of program and the nature of the random or non-logical sequences.²⁹

²⁷Arnold Roe, "A Comparison of Branching Methods for Programmed Learning," Journal of Educational Research, Vol. 55, No. 9, 1962, pp. 407-416.

²⁸Herbert R. Miller, "An investigation Into Sequencing And Prior Information Variables In A Programmed Instruction Unit For Junior High School Mathematics," Paper presented at the DAVI Convention, Milwaukee, 1965.

²⁹Herbert R. Miller, "Sequencing and Prior Information in Linear Programed Instruction," A. V. Communication Review, Vol. 17, No. 1, 1969, pp. 63-76.

In a series of studies³⁰ conducted in working out his theory of a hierarchy of learning competencies, Gagne emphasized the concepts of sequencing pre-requisite knowledge and of differences in entry level repertoires.

Stolurrow³¹ used a random sequence and a logical sequence of a program designed to teach fractions to handicapped high school students to study the interaction between I. Q. and sequence. The random sequence proved too difficult for all but those of higher ability. However, all of the group were successful with the logically sequenced program.

Stolurrow concluded that the effectiveness of sequencing may depend on the learners' ability. The high ability subjects could learn in spite of poor sequencing while lower ability students needed

³⁰ Robert M. Gagne and Larry T. Brown, "Some Factors In The Programing of Conceptual Learning," Journal of Experimental Psychology, Vol. 62, No. 4, 1961, pp. 313-21.

Robert M. Gagne and Noel E. Paradise, "Abilities and Learning Sets in Knowledge Acquisition," Psychological Monographs, Vol. 75, No. 15, 1961.

Robert M. Gagne, "The Acquisition of Knowledge," Psychological Review, Vol. 69, No. 4, 1962, pp. 355-65.

Robert M. Gagne, John R. Mayor, Helen L. Garstens, and Noel E. Paradise, "Factors in Acquiring Knowledge of a Mathematical Task," Psychological Monographs, Vol. 76, No. 7, 1962.

³¹ Lawrence M. Stolurrow, "Social Impact of Programmed Instruction: Aptitudes and Abilities Revisited," Educational Technology, ed. John P. Dececco, (New York: Holt, Rinehart and Winston, 1964) pp. 348-55.

good sequencing to progress through the program successfully. While this was yet another study using mathematical content, it did influence later researchers in programmed instruction to consider the possible interrelationship of learner ability and sequencing effect.

The researchers, in the main, persisted in sampling from college students--probably the most sophisticated achievers in unscrambling obtuse, rambling, disconnected trains of thought among all possible learners. In short, college samples, if skilled in anything, are precisely skilled in learning through random sequence. For example, Payne, Krathwohl and Gordon, using two hundred and thirty-eight college sophomores, found that the hypothesis that the scrambling of frames would interfere most with topics having the greatest logical development was not substantiated. They also found no confirmation for the hypothesis that students with high ability might be able to overcome the effect of scrambling better than the low ability students.³²

Another study that bears on the evolution of the main thrust of this study is a forerunner of the study that will be discussed last in this review of the research on sequencing. Nancy Hamilton,

³² David A. Payne, David R. Krathwohl and John Gordon, "The Effect of Sequence on Programmed Instruction," American Educational Research Journal, Vol. 4, No. 2, 1967, pp. 125-32.

using a program on music fundamentals with fifth and sixth graders, tested four versions of her program on two variables: Sequence versus non-sequenced and two overt responses, specific (fill in response required) versus non-specific (answer already filled in). She found the non-specific response mode superior to the specific mode, with a mean gain in the posttest score significant at the .05 level. She also found that the sequencing variable had a very powerful interaction with the response-mode variable, such that the random specific version was the least successful, and the random non-specific version was the most successful, of all the four treatments.

Miss Hamilton suggests that some sub-levels of frame ordering can be disrupted within an overall logical sequence without interfering with the necessary step-by-step building of the concept or concepts to be learned. She also suspects that the effectiveness of sequencing may depend upon the number and priority of concepts which must be mastered before reaching the criterion task.³³

This writer doesn't quarrel with her finding that the above phenomena lends evidence to the notion that randomizing the sequence of frames probably does not impede the learner and may well provide him with a useful form of actively organizing responses

³³ Nancy R. Hamilton, "Effects of Logical Versus Random Sequencing of items in an Autoinstructional Program Under Two Conditions of Overt Response," Journal of Educational Psychology, Vol. 55, No. 5, 1964, pp. 258-66.

if all pertinent information is available to the learner, if the concepts to be gained are few and simple, and if the randomizing is within a sub-unit. However, bearing in mind that the worse performance also involved non-sequencing, we should ask if there could be a factor in the specific response (filling in the answer blanks) that might impede or prevent actively organizing a response. That factor might involve something like confidence in the learner's progress. The learner in the fill-in sequence was getting no confirmation--no feedback to indicate he was or was not having success at reassembling the content. It might be fair to speculate that ability to conceptually organize or reorganize would require a certain degree of confidence whether from previous related achievements or from sufficient on-going feedback.

The excellent book by Gagne on his theory of hierarchical learning,³⁴ as well as Briggs' book on the relationship of sequencing to Gagne's Hierarchies,³⁵ influenced several researchers to consider Gagne's findings of a hierarchical relationship to the effects of sequencing. These studies have brought us closer to more consistent findings on sequencing even though an assuredness of statistical significance has not yet been reached.

³⁴ Robert M. Gagne, Conditions of Learning, New York: Holt, Rinehart and Winston, 1965.

³⁵ Leslie J. Briggs, "Sequencing Of Instruction in Relation to Hierarchies of Competence," American Institute For Research In Behavioral Studies, Palo Alto, California, 1967.

In trying to depict the required behaviors needed to reach a criterion task in mathematics, Gagne drew a hierarchical diagram of the subordinate skills, arranged in layers and indicated the sequence in which the subordinate parts of the task should be taught.

He theorized that the competencies so identified serve as mediators of positive transfer from lower level competencies to higher ones and that starting with the learning of the lowest levels, attaining each higher level depends on positive transfer, recall, and the effects of instruction in guiding thinking. At the very bottom of the hierarchy may be found relevant competencies supposedly learned earlier and basic abilities relevant to the learning of the task.³⁶

Gagne proposed that if a program were perfectly effective everyone would achieve all the levels in each particular hierarchy and test variances would be zero; that all correlations of tests on the levels of competency and basic abilities would also be zero. However, if the programs were not completely effective, an individual's achievement in a level of competency would be related to his score on a test of the relevant basic ability.

In dealing with individual differences, he used programs designed to reach the criterion task of solving linear algebraic equations. He developed, through logical analysis, a hierarchy of six levels of relevant competencies and he determined that three specific relevant abilities should form the base of this hierarchy.

³⁶ Leslie J. Briggs, "Learner Variables and Educational Media," Review of Educational Research, Vol. 38, No. 2, 1968, p. 161.

Using this construct in his research, he found that the "... rate of learning depends decreasingly on relevant abilities, whereas the achievement of the learning set depends increasingly on such abilities as one goes up the hierarchy."

Gagne's work encouraged research into the relationship of sequencing to the nature of the content to be learned in a program, the influence of some kinds of abilities in sequencing effectiveness and the need for entering competencies for any given learning set.

Wodtke³⁷ and his associates hypothesized that scrambling an instructional sequence involving hierarchical concepts would be very detrimental to learning, but if the content matter were not closely interrelated, scrambling the sequence would not affect learning. It was also hypothesized that scrambling would be most detrimental to low ability students but would not affect high ability students.

A program on modern mathematics was used for instruction involving hierarchical concepts and the anatomy of the ear was used for a program of content that was not closely related. Again, there is a mathematics program and again the subjects are college students. And, of course, there was no significant effect of scrambling in either program although as usual the logically sequenced versions did better. Surprisingly, for this level of subject, tentative support was given to the hypothesis that an ordered sequence is more important to the learning of low aptitude

³⁷Kenneth H. Wodtke, Bobby R. Brown, Harold R. Sands and Patricia Fredericks, "Scrambled Versus Ordered Sequencing in Computer Assisted Instruction," Pennsylvania State University College of Education, University Park, 1967.

students.

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Niedmeyer, Brown and Sulzen compared three sequence versions (logical, scrambled and reverse frame orders) of the guided discovery program, Number Series, used by Gagne and Brown in their 1961 study.³⁹ Sixteen ninth grade algebra students in each of the three sequence groups plus a control group served as the subjects. While the logical order group was the only sequence group to perform significantly better than the controls on both a test of concepts and a problem-solving test, none of the three sequence groups differed significantly from each other on post-test performance. This fact plus the fact that the mean I.Q. for each group was between 111 and 112 and the variances within each group were not statistically different, would seem to indicate that the content involved was not beyond the subjects' comprehension even without the aid of the program. In their discussion of the relationship of I.Q. and performance, the three authors state: "It seems that aptitude, rather than sequence, determined how well an individual learner would do under all three sequence conditions."⁴⁰ Unfortunately, their design was not set up to see if sequence would help any low aptitude level of learners. In view of the composite but seemingly homogeneous grouping of aptitudes and the relative ease of the content, it is not surprising that the authors concluded: "The students in the scrambled and reverse order sequence groups apparently were capable

³⁸Fred Niedmeyer, Jerry Brown and Bob Sulzen, "Learning And Varying Sequences of Ninth-Grade Mathematics Materials," The Journal of Experimental Education, Vol. 37, No. 3, 1969, pp. 61-66.

³⁹Gagne and Brown, op. cit.

of integrating and organizing information regardless of the sequence of presentation."⁴¹

Lastly, Herbert Miller conducted an outstanding experiment using four treatments of the sequencing ^{of} units in matrix arithmetic.⁴² He divided the sequencing of these units into "Macro-orders" and "Micro-orders." The presentation of the sections--that is, definitions, addition of matrices and multiplication of matrices--served as macro-order and the order of development within the sections as micro-order.

Subjects were not pretested on matrix arithmetic because pretesting would have damaged the prior information variable, and it was determined that the experimental subjects had not studied matrices as a part of their regular curriculum.⁴³

The prior information consisted of an outline specifying the definitions and operations to be covered in the program. One-half of the subjects in the study received a page with the outline on it.

In this design the affective effects of prior knowledge--in the limited way that term was used in this experiment--were measured by use of a shortened version of Mood Adjective Check List. No significant differences were found on any of the dependent variables.

⁴¹Ibid., p. 67.

⁴²Herbert R. Miller, "Sequencing and Prior Information in Linear Programmed Instruction," A. V. Communication Review, Vol. 17, No. 1, 1969, pp. 63-76.

⁴³Ibid., p. 67.

In both substudies the treatment groups that registered the better performances on the multiplication portion of both the criterion and retention measures were those in which macro-order was preserved. Miller finds that this result

. . . would seem to be consistent with Gagne's notion of the existence of hierarchies of learning tasks. In order to achieve a specific overall objective, there may be subordinate tasks which must be accomplished in a particular order.⁴⁴

He further found that the fact that the subjects performed as well on non-logical as on logical sequences with respect to the definitions and addition of matrices tended to confirm suggestions from other investigators that students can rearrange information effectively. He specifically mentions Bousfield's work on the phenomena of clustering and he further relates this work of Bousfield to Hebb's account of superordinate and subordinate perceptions.⁴⁵

Miller reaches the general conclusion that the sequence of frames does not make a difference as long as the order of concepts is preserved.

In particular, if certain tasks are subordinate to some higher level tasks, these tasks must be accomplished in the proper sequence. As long as this condition is met, the actual sequence of frames may not be of importance.⁴⁶

⁴⁴Ibid., p. 72.

⁴⁵W. A. Bousfield, "The Occurrence of Clustering In the Recall of Randomly Arranged Associates," The Journal of General Psychology, Vol. 49, 1953, pp. 229-40.

Donald O. Hebb, The Organization of Behavior New York: John Wiley, 1949.

⁴⁶Miller, op. cit., p. 73.

This design depended on mathematical processes and thereby leaves the question of the degree of familiarity or confidence in dealing with the content somewhat open. It also is disappointing that Miller did not put his potent design, its results, the observations of Hebb and Bousfield together in a different way but a way that seems as well justified. A way that may also be complementary and additive to Gagne's work in hierarchies of learning.⁴⁷ It would seem that Hebb's chapter, "Perception Of A Complex: The Phase Sequence,"⁴⁸ especially that part where he discussed ". . . the question of an integration of the several parts of a figure into a distinctive whole, as contrasted with the amorphous whole that is perceived in first vision," (underlining is writer's) applied equally as well as Gagne's work.

In discussing his own research, Bousfield stated:

The results of this study have indicated that subjects, when given a list of randomly arranged items will in their recall show a greater-than-chance tendency to group the items in clusters containing members of the same category. This implies the operation of an organizing tendency.⁴⁹ (Under-scoring is writer's.)

Miller himself found the results showing no significant differences in the simpler mathematical process as tending to confirm the suggestions "that students can rearrange information effectively."⁵⁰

⁴⁷Robert M. Gagne, "The Acquisition Knowledge," Psychological Review, Vol. 69, No. 4, 1962, pp. 355-65.

⁴⁸Hebb, op. cit., pp. 79-106.

⁴⁹Bousfield, op. cit., p. 237.

⁵⁰Miller, op. cit., p. 73.

Disappointingly, when he found that the logical sequencing of the macro-order aided in the satisfactory acquisition of the more complex mathematical process, he did not connect this phenomena to some possible progression of mental organization or cognitive capacity that had reached a level of difficulty wherein the sequencing was able to help in the increase of mental organization or the expansion of the conceptual scope.

Briefly summing up the research on the technique of sequencing in programmed instruction: that stage in an evolutionary process of research on the effects of sequencing has been reached where the research effort planned for this paper may be able to make a further contribution. It may be able to determine whether the sequencing techniques used in this experiment only becomes crucial at the point where the learner needs help in arranging or ordering the concepts involved in the learning content.

Cueing

The literature on cueing, though more limited, indicates the same overall research denouement as that in the literature on sequencing. There is still a need to consider whether cueing becomes critical only at the point where the cognitive capacity cannot assimilate, unaided, the content concepts. The literature does indicate that a concomittant concern might be the question of whether unnecessary cueing--where cognitive capacity is adequate to the task of unaided assimilation--causes learning impairment.

Irving Goldberg defined cues (or prompts) as: "Aids that are incorporated in some frames to enable the learner to respond correctly."

He also defined Fade or Vanish as: "Terms applied to the gradual decrement of cues during a program." ⁵¹

The studies that follow are related to this needed knowledge about cueing.

Smith and Moore⁵² point out that the concern about cueing is based on the desire to increase the probability that a student responding to any given item will make the correct response. They hypothesized that strong cueing (to assure minimal error rates in response) might not produce the highest scores on a criterion measure. The results of their study on the learning of sixth grade spelling words where strong or overt cueing by use of pictorial prompts produced no significant difference allowed them to conclude that "... strong cueing to assure the eliciting of the correct response to the frame of a program may have been overemphasized."

Angell and Lumsdaine⁵³ tested subjects to compare learning with standard confirmation technique to partial cueing. Little

⁵¹Irving A. Goldberg, "Introduction to Programed Instruction," Applied Programed Instruction, ed. by Stuart Margulies and Lewis D. Eigen, New York: John Wiley and Sons, Inc., 1962.

⁵²Wendell I. Smith and J. William Moore, Programed Learning: Theory and Research, D. Van Nostrand Company, Inc. Princeton, New Jersey: 1962, pp. 202-6.

⁵³David Angell and Arthur A. Lumsdaine, "A Study of Subject Controlled Partial Cueing in Paired Associate Learning," American Institue for Research, San Mateo, California: 1961.

overall difference was found between the two methods. However, when the items were dichotomized into difficult versus easy ones, the partial-cueing procedure was found to be somewhat more effective for slow learners with hard items and somewhat less effective for fast learners with easy items.

Crist's⁵⁴ data indicate that partial prompts more than tripled the ability of the lower third of his subjects to make the "preferred" response while the upper two thirds made only fractional gains.

Kornreich⁵⁵ used two Bruner referenced terms of "focusers" and "non-focusers" in his research on information processing. The "non-focusers" or non-understanders could not learn with respect to the task set before them. The "focusers" or understanders could learn with respect to the task set before them. He found that the "non-focusers" did not do well at holding all the information (4 hypotheses) needed to solve trial #2. However, with only two remaining hypotheses to retain on the third trial, they did much better. Kornreich found that when only two hypotheses had to be remembered, the lack of perceptual aids did not seem critical.

⁵⁴ Robert L. Crist, "Group Use of Programmed Instruction As A Means of Generating Homogenous Study Groups," A. V. Communications Review, Vol. 17, No. 2, 1969, pp. 201-9.

⁵⁵ L. Berell Kornreich, "Strategy Selection and Information Processing in Human Discrimination Learning," Journal of Educational Psychology, Vol. 59, No. 6, 1968, pp. 438-48.

Studies of prompting and confirmation by Seidel and Hunter⁵⁶ indicated that while cueing techniques helped motivate their subjects and helped to improve their scores during the learning phase, these same techniques seemed to cause a decrement in ability to apply what they learned. In these particular studies, however, the prompting appeared to more akin to over prompting.

Another study which indicated that too much prompting has a deleterious effect is one done by Angell and Lumsdaine⁵⁷ on the vanishing of verbal cues. Subjects were given two versions of a program. The first one employed vanishing, that is, the progressive reduction of prompts. The second one was a non-vanishing version of the program. Immediate testing did not reveal a significant difference but two weeks later the scores on a delayed retention test were significantly higher for the vanishing than the non-vanishing treatment.

Lastly, a study by Anderson and Faust⁵⁸ showed that the

⁵⁶Robert J. Seidel and Harold G. Hunter, "The Application of Theoretical Factors in Teaching Problem Solving by Programed Instruction," Technical Report 68-4, Human Resources Research Office, George Washington University, 1968.

⁵⁷David Angell and Arthur A. Lumsdaine, "Retention of Material Presented by Auto-instructional Programs Which Vanish and Which Do Not Vanish Verbal Cues," American Institute for Research, Palo Alto, California, 1962.

⁵⁸Richard C. Anderson and Gerald W. Faust, "The Effects of Strong Formal Prompts in Programed Instruction," American Educational Research Journal, Vol. 4, No. 4, pp. 345-52.

version of a program which had underlined response terms was less effective than the version in which the subject was required to give more attention to determining the correct response.

Again the research design of this study is intended to help determine whether there is some critical level of learner ability where cueing technique will aid in successfully attaining the desired learning.

Group Pacing

If we are to consider accommodations between the ultimate in adjusting to individual differences and the meager funding for innovation available to many educational systems, we must give serious study to group pacing. In group pacing the technique of individualized involvement with programmed instruction is replaced with involvement as a group. The research has been concerned about whether individualized involvement can be eliminated without impairing the direct attention and concentration that is elicited in self-paced programs.

Again the literature is limited, probably because of the difficult nature of specific term definitions in this area of program use. That is, just what is the difference in the amount and quality of response when learning is group paced? The literature that is available indicates successful response involvement in that there is a frequent finding of no significant difference between the group pacing technique and individual pacing.

Equal effectiveness seems most assured where the paced groups are homogeneous. If this is so and individual attention

within the group can be harmoniously sustained, then this would certainly be an economical use of programmed courses. Some of the positions and findings on group pacing follow.

D. L. Moore⁵⁹ argues that group teaching by programmed instruction offers efficiency at a certain cost to the individual but an overall gain for the group.

Carpenter and Greenhill⁶⁰ found that programmed materials could be pre-paced and presented to groups of college students without significantly reducing the learning in comparison to self-paced study.

James Hartley⁶¹ in a paper presented to the 3rd International Conference on "Problems of Programmed Learning and Teaching Machines in Lidice, Czechoslovakia, in May of 1967, marshals an extensive list of studies to back up his two main arguments:

1. Self-instruction may not be as effective in some situations as working in pairs or small groups.
2. External forms of pacing may in some cases lead to more efficient learning than does self-pacing.

⁵⁹D. L. Moore, "Group Teaching by Programmed Instruction," Programmed Learning and Educational Technology, Vol. 4, No. 1, 1967, pp. 37-46.

⁶⁰Clarence R. Carpenter and Leslie P. Greenhill, "Comparative Research on Methods and Media for Presenting Programmed Courses in Mathematics and English," University Park, Pa.: University Division of Instructional Services, The Pennsylvania State University, 1963.

⁶¹James Hartley, "Some Factors Affecting Student Performance in Programmed Learning," Programmed Learning and Educational Technology, Vol. 5, No. 3, 1958, pp. 206-218.

Many of the studies cited have rather small Ns. As Hartley points out, most of the group programs were based on programs developed for individual pacing. He also drew attention to findings that not all students in the self-paced condition operate in an efficient manner.

Frye⁶² used programmed materials with homogeneous groups and with heterogeneous groups. Confirmation of the correct response was held until the slowest student had indicated his answer (pressed a button). This procedure was effective with homogeneous groups but was ineffective with heterogeneous groups because the differences in response times were too great.

Robert Crist found a defect attending the group use of programs in earlier research. ". . . Many Ss read the frame only after being called upon and then read only enough of the frame to be sure their response was correct."⁶³ In his group paced program the preferred responses were put back into the frames and words that would be less likely derived from the context were blacked out. (As a prompt the word was also substantially blacked out--bottom 75%.) He found that homogeneous groups could be tentatively identified on the basis of I.Q., making the later movement of students resulting from actual performance relatively small. His

⁶²Charles H. Frye, "Group vs. Individual Pacing In Programed Instruction," Oregon State System of Higher Education, 1963.

⁶³Crist, op. cit., p. 202.

initial sample was an intact junior high school classroom having 27 students. His data showed that the low achievers were helped markedly in making correct responses by the prompt frame.

Crist⁶⁴ did an earlier study to test the hypothesis that peer influences, generated by the group condition, would sustain student attention and effort and thus would have the following two effects:

An increase in learning over that occurring when the programmed textbook is studied under the individual self-paced condition, and emergence of a group of students with retention scores sufficiently similar to justify their being labeled "homogeneous".

Uncontrolled variables caused somewhat mixed results but the experimenter felt confident that the results favored his hypothesis.

In an early study on group pacing Gropper and Kress⁶⁵ made a finding that is of interest to this particular study. While investigating the use of pacing as a means of achieving a more efficient rate of working than that obtained under self-paced conditions, they found evidence that many students have unadaptive natural working rates, and suggested that it might, under some circumstances, be beneficial to replace self-pacing by some form of external pacing.

The design of this experiment should indicate how different levels of learner ability are affected by group pacing as compared

⁶⁴ Robert L. Crist, "Role of Peer Influence and Aspects of Group Use of Programmed Materials," A. V. Communication Review, Vol. 15, No. 4, 1967, pp. 423-34.

⁶⁵ George L. Gropper and Gerard C. Kress, "Individualizing Instruction Through Pacing Procedures," A. V. Communication Review, Vol. 13, No. 2, 1965, pp. 165-182.

to individual pacing of the program and whether individual pacing and responding are more critical to the learning of one group than to another.

Hypotheses

The writer hopes to show that there is some factor such as cognitive capacity operating in learning situations, and that the effectiveness of the techniques for aiding the learner which are commonly used in programmed instruction depends on the magnitude of this capacity. That is: These programming techniques are only effective when the conceptualization required by the program begins to strain the unaided cognitive capacity of the learner.

While at first glance a very close relationship might seem to indicate that cognitive capacity is the exact same as achievement level, this is not so. If it is the same as achievement level, there will be no sex difference in performance. However, previous research findings indicate that in block design problems there will be a difference in favor of boys.⁶⁶ If the program had verbal learning content in music or sewing, there might well be a difference favoring girls. The point is that there are influences other than just aptitude--as measured in achievement tests--involved in the cognitive scope. In this study, the effects of sex difference will be considered as one such influence.

While this approach calls for a three-way factorial design,

⁶⁶Eleanor Maccoby, "Sex Differences in Intellectual Functioning," The Development of Sex Differences, edited by Eleanor Maccoby, Stanford University Press, Stanford, California, 1966, p. 26.

it still allows an analysis that is fairly simple. It can be used in future research where the sex difference can be substituted with factors such as attitude or confidence differences.

With regard to the considerations discussed in this chapter, the following hypotheses have been offered:

- H_{1A} : Performance on the criterion problem will be affected by the variations in the program.
- H_{1B} : Performance on the criterion problem will rank in the following descending order:
1. The program.
 2. The paced program.
 3. The cueless program.
 4. The mixed sequence program.
- H_{1C} : Performance on the criterion problem will be least affected by program variations in the high ability level.
- H_{1D} : If performance on the criterion problem for any one level of ability is adversely affected by one of the variations in the program, then the performance of any lower ability levels will also be adversely affected by the same program variation.
- H_{2A} : Performance on the criterion problem will be affected by the ability levels.
- H_{3A} : Performance on the criterion problem will be affected by sex.
- H_{3B} : The performance of the boys on the criterion problem will exceed that of the girls.
- H_{3C} : The sex difference in performance on the criterion problem will be least at the high ability level.

For the purpose of evaluation, the research hypotheses formulated above have been stated in the following statistical hypotheses:

- | | | | |
|----------------|---|---|---|
| H ₁ | : | Main Effect Program treatments_____ | 0 |
| H ₂ | : | Main effect ability levels _____ | 0 |
| H ₃ | : | Main effect sex_____ | 0 |
| H ₄ | : | Interaction program treatments X
ability levels_____ | 0 |
| H ₅ | : | Interaction program X treatments
sex_____ | 0 |
| H ₆ | : | Interaction ability X sex_____ | 0 |
| H ₇ | : | Interaction program X program
treatments sex_____ | 0 |

The results from the evaluation of the statistical hypotheses stated above have been interpreted in the light of the general research design of a 2 x 3 x 5 analysis of variance which served as a starting point for a series of multiple analyses. The elements of the research design are presented in the array of the cell matrix in Table No. 2 and in the graphic depiction of the cells in Illustration No. 7.

Summary

If it can be established that there is a factor such as cognitive capacity which interacts with the programming techniques of cueing, sequencing, and responding, then research designs for these areas should be refined to account for this factor. Such designs should be relatively simple, easily replicated, and should try to insure findings that would have the universal validity of good technology.

Such designs should:

1. Have a reasonably adequate number of subjects.
2. Be free of processes with which the subjects may have varying degrees of confidence and familiarity.
3. Be free of word ambiguity.
4. Use learning materials that are culture and sub-culture free.
5. Use a population of learners that have not become highly selective.
6. Make some division of the total sample of learners into homogeneous ability groupings.

The research design in this study will meet the above requirements and is expected to indicate that techniques which aid in the learning process--particularly response involvement, cueing and sequencing--will not show effectiveness until the concepts in the material to be learned become challenging and difficult for the learners' existing cognitive capacity. Since this capacity is a matter of individual difference, it will vary as individuals differ and the effects of helping techniques will only be measureable when the content becomes difficult for the individual's cognitive capacity to encompass.

CHAPTER II

PROCEDURE

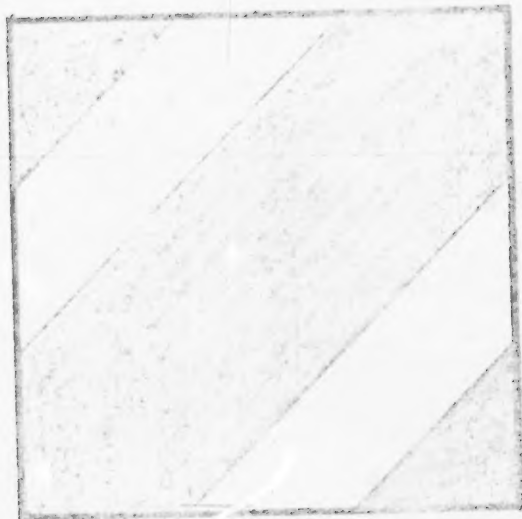
The seventh grade level was chosen for this research in an attempt to study a broad range of learner ability that would be available before student dropout too heavily biases most academic groups toward only the successful achiever.

A program of seven frames was developed to aid seventh grade level pupils to rapidly solve a criterion problem (see Illustration No. 1). It was sequenced from simple to complex and the cues were gradually faded out. The frames and the entry level and criterion problem were non-verbal. They ~~were~~ ^{USED} one inch cubes which had four solid colors of red, white, blue and orange and two combinations meeting on a diagonal of red-white and blue-orange. (See Illustration No. 2.) The program was developed and validated on seventh grade pupils in a nearby county.

The frames were a series of block design problems which in the normal program were sequenced in a simple to complex format with initial heavy cueing gradually vanished. (See Illustration No. 3.)

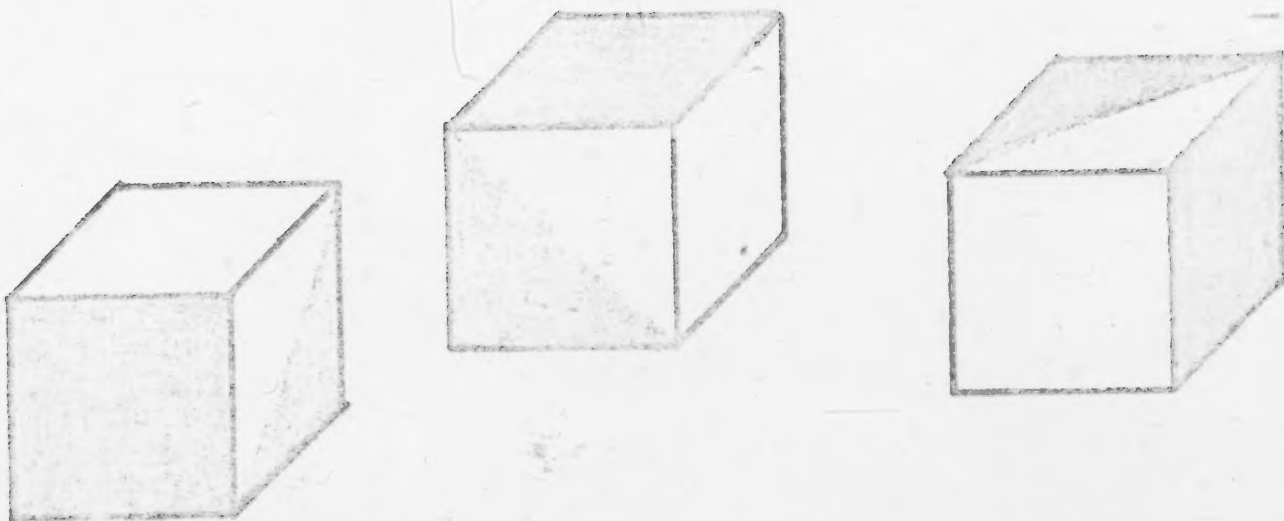
¹ Samuel C. Kobs, Intelligence Measurement, New York: Macmillan, 1923.

ILLUSTRATION No. 1



Critexion Problem

ILLUSTRATION No. 2

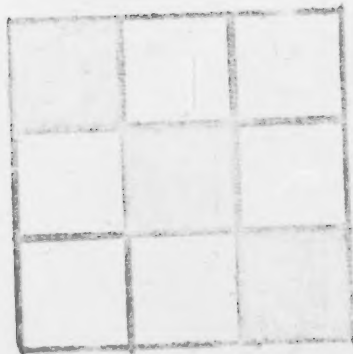


Blocks for solving design problems.

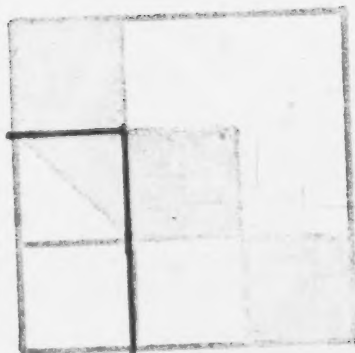
(One inch cubes. Red and white colors.)

ILLUSTRATION NO. 3

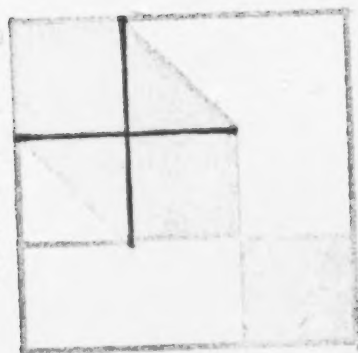
Frame 1



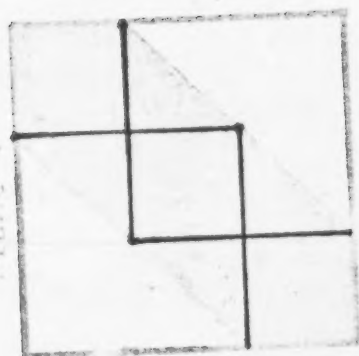
Frame 2



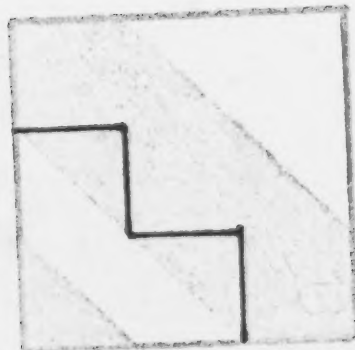
Frame 3



Frame 4



Frame 5



Frame 6



Frame 7



The process: Each problem is on a separate card (frame).

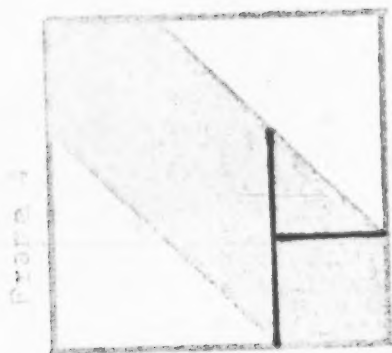
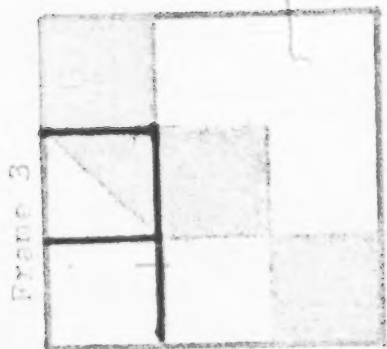
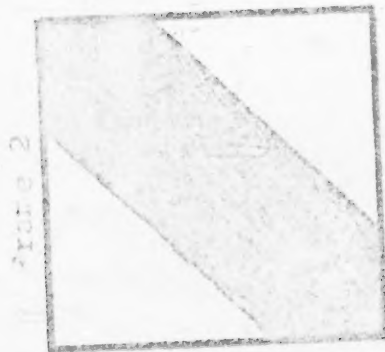
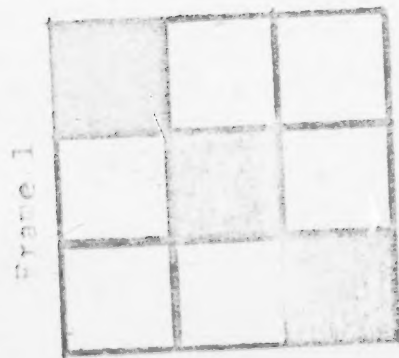
(Actual size of design was approximately 3 3/4" square.)

The objective of this very brief sequence was to gain insight that would allow the rapid solution of a new (that is, not previously seen) but sequentially related criterion problem. Two alternate versions were made by:

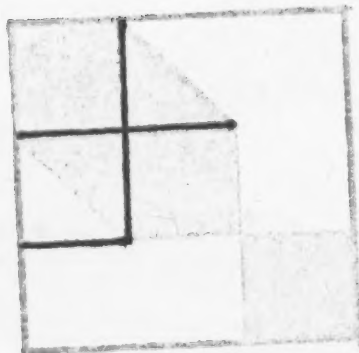
1. Mixing the sequence of the programmed frames in this order: 1, 7, 2, 6, 3, 5 and 4. (See Illustration No. 4.)
2. Removing the cues--that is, the lines that indicated how some of the blocks should be arranged. (See Illustration No. 5.)

Since results were based on the time it took to complete the criterion problem and since it was desirable to neutralize any relative difference in ability to handle a spatial relationship type problem, an initial or entry level problem, an initial or entry level problem was used for all treatments. This consisted of a relatively simple design which involved using the three sides of the blocks that were used in the program and criterion problem. (See Illustration No. 6.) This pre-entry test was also highly cued. In effect the solution was so easily discernible that only a deficiency in grasping spatial relationships or in manual dexterity would impair the solution. Therefore, this score is used as a simple weight to neutralize the variation in ability with spatial relationships and differing rates of manual dexterity, if any existed. That is, the time to solve the entry level problem is subtracted from the time to solve the criterion problem.

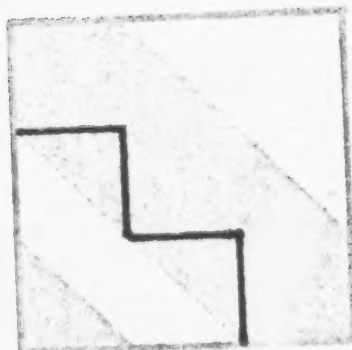
ILLUSTRATION NO. 4



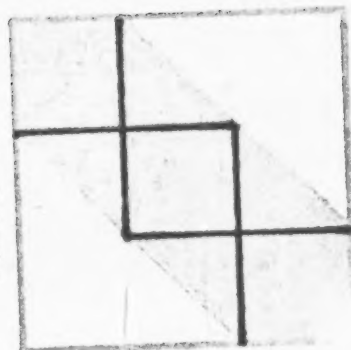
Frame 5



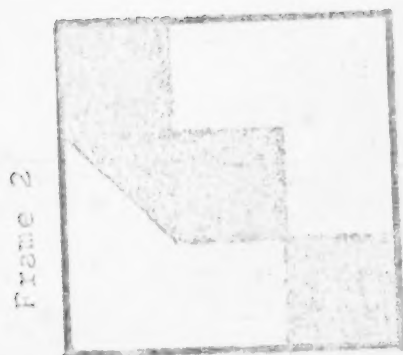
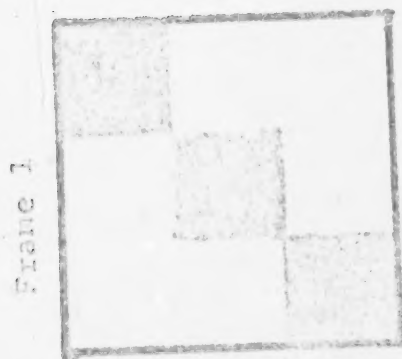
Frame 6



Frame 7

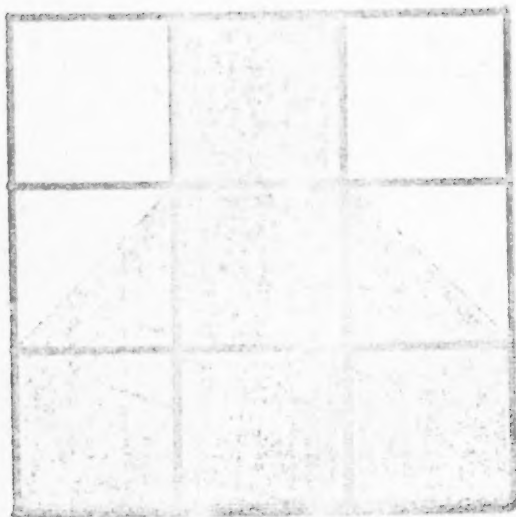


The Mixed Sequence Treatment of the Program.



The Treatment of the Program that has the cues removed.

ILLUSTRATION 1.1.6



Entry Level Problem

The following five treatments of the program were developed for this experiment:

1. A control group which received only the entry level problem and the criterion problem.
2. A group which received the entry level problem, the program as it was developed, and then the criterion problem.
3. A group which received the entry level problem, then put their blocks in a bag while they worked through the normal program with the writer acting as teacher and group pacer. The students were not required to respond but were asked as a group to work the problem out with the writer, and to tell him if and when he arranged a block incorrectly. When the program was finished, the subjects dumped out their own blocks and did the criterion problem.
4. A group which received the entry level problem, then the version that had the cues removed from the frames, and then the criterion problem.
5. A group which received the entry level problem, then the version of the program that had the sequence mixed in a 1, 7, 2, 6, 3, 5, and 4 order and when finished the criterion problem.

In a previous tryout of the third technique with a restless group of low achieving eighth and ninth grade boys, the writer obtained

extremely poor results as compared to the results of the other treatments. Because of inattention and horseplay, most of the subjects in this treatment failed.

The intent of the group pacing treatment had been primarily to test the effect of preventing the response that is required in the other treatments, so copies of the program were not given out. The blocks were not given to the subjects until after the group paced program was completed. The blocks were then given out and the initial problem was administered followed by the administration of the criterion problem. This insured that there would be no opportunity to interact with the blocks. In other words, the program mode of response was denied. The results cited above made the writer rather apprehensive about this treatment and the possible researcher bias described by Rosenthal.²

Therefore, for this study, several modifications were made in this treatment. Briefly, they were these:

1. The initial problem was completed first. Then each subject put the blocks in a paper bag in his carrel.
2. Each subject had a copy of the program in front of him in his carrel.
3. Even the low achieving group was very cooperative and the inattention/discipline problem was not present.

Responses were spontaneous and well concerted.

Population

Thanks to the empathetic understanding of research requirements by the school officials in the suburban area of Washington, D. C.

²Robert Rosenthal, Experimenter Effects in Behavioral Research, New York: Appleton-Century-Crofts, 1966.

where this experiment was conducted, one intermediate school's entire seventh grade of 424 pupils was used as the initial pool. The pupils were from a predominantly white middle socio-economic class background. Scores from the Lorge-Thorndike Battery which had been administered in the sixth grade were used to separately rank order the boys and the girls. Both orders of scores were matched to make comparable thirds in each ranking. (See Table I.) Thus, the lower range went from scores of 77 to 98 for girls and from 76 to 98 for boys. The middle range went from 100 to 112 for both boys and girls. The upper range went from 118 to 137 for girls and from 113 to 138 for boys.

TABLE I
MATCHED SETS OF LORGE-THORNDIKE SCORES

Low	77 to 98	Girls
Range	76 to 98	Boys
Middle	100 to 112	Girls
Range	100 to 112	Boys
High	118 to 137	Girls
Range	113 to 138	Boys

The computer program which will be used to run the multiple analysis of variance requires equal numbers of subjects in each cell. Due to the imbalance of the numbers between the sexes (231 girls and

193 boys) and the absence of aptitude scores for some students who had transferred into the school system, the optimal number in each range turned out to be 50. Students were randomly cast out of each range until 50 remained. Since there were five treatments for each sex, each set of 50 pupils was randomly distributed into the five treatments. Thus, there were 10 randomly assigned students to each cell of the design matrix. (See Illustration No. 7.) From an initial pool of 424 students, there remained 300 for the experiment. Since the computer program required an equal number in each cell, any pupil who remained absent throughout the testing period forced a like drop in the number of all the other cells. Fortunately such absences only reduced the number to nine in each cell. Where there were more than nine in a cell one of the students was randomly cast out.

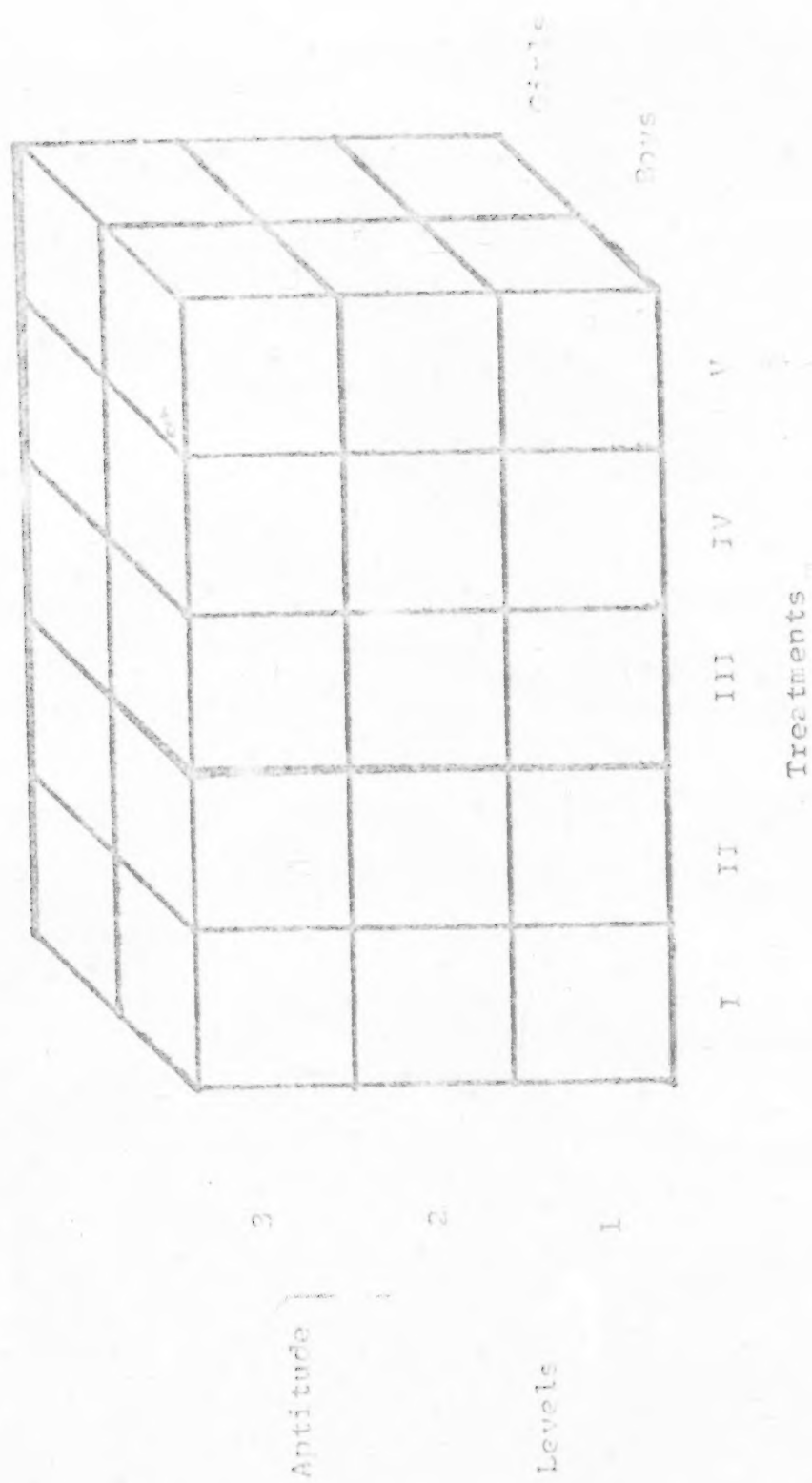
Thus, from the initial pool of 424 seventh graders, the performance scores of 270 were useable for computation.

Research Design

The purpose of this research is to study the effects of each treatment on three levels of aptitude by sex. Therefore a $5 \times 3 \times 2$ factorial design will be used. (See Illustration No. 7.) This design offers simultaneous tests that can show whether the whole distribution of the obtained data could have happened by chance. Assuming that the variances from the various samples are homogeneous, and applying the null hypothesis to all the samples, we can use all the data to give us a more stable estimate of population variance. As can be seen from our subordinate hypotheses, interactions or at

ILLUSTRATION No. 7

5 x 3 x 2 Factorial Design



tendencies toward diminishing differences were not only anticipated but they were expected to occur in a certain way. The treatment and sex factors are expected to show less differences as they progress from the lower to the higher aptitude level. Or, put another way, differences between treatments and between sex are expected to decrease as the aptitude level increases. Conversely, the differences at the lower level of achievement will tend more toward significance. To demonstrate this, further comparisons were made by successively reducing the factorial design from $2 \times 3 \times 5$ to 2×5 , 1×5 , $2 \times 3 \times 4$, 2×4 , and 2×2 .

In dividing each group or treatment by sex and by levels of aptitude, we have thirty cells of nine students each. Time to complete the criterion problem minus the time to complete the entry level problem will be the dependent variable.

Procedure

The school made available a comfortable, well lighted room with ample space. Carrels were made to fit on the tops of the tables in the room. The sides of the carrels were one foot high. The carrels gave each pupil the privacy needed to work independently of other pupils. A timer, which recorded to one-tenth of a second was located in each carrel as well as a set of nine one-inch blocks, a pencil and score sheet. Twenty carrels were made so that boys and girls from comparable cells were processed at the same time and thus were subjected to the same audience.

When the pupils were quietly seated and had filled in their name, homeroom and their "code number" (the treatment number of their cell) on their score sheet, they were thanked by the writer for coming to help him in an experiment about learning. It was pointed out that--

like good scientists--each one of the must follow instructions in doing their particular part of the experiment, that it was important not to discuss their part in the experiment until all the students had a chance to complete their part. (Judging from comments of pupils in subsequent cells, the students gave remarkable cooperation in this as in all the things that they were asked to do.) The pupils were asked to check to see that they had nine blocks. Next they were asked to pick up one block and examine it as the writer also examined a block. It was pointed out that each block had a solid red side, a solid white side, and a half-white-half red side (the diagonal split was obvious by inspection and therefore not verbally described). (See Illustration No. 2.) The pupils were told that all designs would be in red and white only so that they would only need the three sides which were examined. The designs would be on cards which would be placed face up in their carrel. Their timer would be started as soon as the card was presented. They were to create the design that was on the card using all nine blocks. They were not to put the blocks on the design but beside it. As soon as they had finished and had compared their design in blocks against the design on the problem card, they raised their hand and the observer stopped the timer and checked the design. The time for the initial problem was recorded and the student was started on the next phase of his particular treatment. Treatment 1, the control group, was next asked to mix up their blocks and were given the criterion problem. The timing procedure was the same as for the initial problem. For many

students this was a frustrating situation but all the students were encouraged to give their best effort. In Treatment II the program was interspersed between the initial entry problem and the criterion problem and the students were encouraged to work through it at their own speed. As they completed each block design in the program, they checked it themselves, scrambled the blocks and proceeded to the next design frame and solved it. When they finished the last frame of the program they raised their hand. The program was removed from the carrel, the blocks were scrambled and the criterion problem was presented. The timing procedure was the same as before. Treatment IV (the program with the cues removed) and V (the program with the frames in the order of 1, 7, 2, 6, 3, 5, 4) were conducted in the same manner as Treatment II, except that students were encouraged to try at least the next frame if they encountered a frame that was too difficult for them. Treatment III was conducted in the following manner: after the initial problem, the students put their blocks in a paper bag. The program was given while each student sat at his carrel. The writer, acting as teacher and demonstrator, paced the group through the seven frames by using a combination of a demonstration and solicited response technique in going through each design (frame) using one set of blocks to demonstrate the solution of each frame. When the program was finished, the students were asked to dump the blocks out of the paper bags. The bags and the programs were removed from the carrels. Then the criterion problem was administered as in the other four treatments.

As each student finished his particular treatment they were

thanked for their cooperation and sent back to their class. No time limit was set for working the criterion problem. However, if after six minutes the student didn't seem to be approaching the solution, it was suggested that, if they were sure they couldn't solve the problem, it was perfectly all right to stop. They were thanked for their persistence and effort.

Measurement

Successful completion within a specified time of the criterion problem versus non-completion within the specified time might seem to be too blunt a measuring device for this program and a comparison of whatever times were required for solution would be a more precise measurement of the effectiveness of each treatment. However, practical scheduling limitations required some cut off time. The writer had observed from previous tryouts of the program treatments that subjects who were able to use knowledge gained from any treatment of the program did so within six minutes. Subjects solving the problem after this length of time seemed to do so through a heuristic approach mainly of their own making. To hold class disruption to a minimum, a six minute limit was set.

However, at the time of the experiment, the outstanding cooperation of the school principal insured a rapid assembling of the pupils and ample time to allow most of the students to work as long as they desired on the criterion problem. Whatever time it took for criterion solution was recorded on the data sheets. All subjects who were still working at the end of six minutes were told that what they were doing was supposed to be a fun exercise and if they weren't having fun

they could give up. Some of them did and their score was recorded as a "gave up". In tabulating scores for statistical processing all the scores that were above 360.0 seconds and all the gave up scores were counted as 360.0 seconds.

The scoring of the time for the entry level problem presented no difficulties. All students completed this design quickly. The time of the entry level test was subtracted from the time it took to solve the criterion problem.

Summary

A multiple factor analysis of variance for three dimensions, different subjects with equal subclass frequencies, fixed model by a least squares solution was applied to the performance scores of the stratified randomly assigned pupils. This $2 \times 3 \times 5$ factorial design was used to measure the effects of three levels of aptitude and sex difference on five treatments of a brief non-verbal culturally-free program designed to enable subjects to solve a criterion block design problem. In relation to the treatment factor and both the classification factors, ten subjects were randomly assigned from an original pool of 424 pupils in a seventh grade class of one school, to each of the thirty cells of the design. The total number of performance scores submitted to analysis of variance consisted of 270 subjects due to absences.

The lower order analyses of variance were processed by use of reduced factorial designs. It was anticipated that treatment differences would tend to disappear at the upper level of ability while at the lower level of ability they would tend toward significance.

CHAPTER III

ANALYSIS OF DATA

As stated in Chapter II, the scores of 270 subjects were used in this study. From the initial pool of 424 pupils subjects were divided by sex and into three groups each of matched ability ranges--low, middle and high. The number above 50 in each ability group was randomly cast out. The remaining 50 in each group were randomly cast into five treatments. This put ten subjects in each sex by ability by treatment cell. These treatments were:

- I. Control group--no program.
- II. Program in normal version of a linear format.
- III. The program paced by the writer, thus substituting verbal group response for individual interaction with learning materials.
- IV. The program with the cues that were in the normal program removed.
- V. The frames of the normal program given in the following mixed sequence: 1, 7, 2, 6, 3, 5 and 4.

The computer program used for three-way analysis required equal numbers

in each cell.¹ Absences at the time of the experiment caused the number in some cells to drop from ten to nine. From those cells that had ten subjects participating in the experiment, one was randomly cast out. Therefore, the scores of nine subjects in each of the thirty cells of the design matrix were computed. Table 2 illustrates the $2 \times 3 \times 5$ matrix design for three way analysis of variance. The criteria used for the evaluation of this study were the raw scores in seconds obtained by subtracting the time to complete the entry problem from the time to complete the criterion problem. In a few cases this gave small minus scores. The scores of those students who gave up or whose effort extended beyond six minutes (the "gave ups" and the underlined scores in Table 3) were treated as scores of 360.0 seconds.

¹Data analysis for this study was executed by the writer on the IBM 1620 Data Processing System of the Computing Center of The Catholic University of America. Wylma R. Curtin, and Jean Warthen, Basic Statistics Programmed for the IBM 1620 Computer (Kensington, Maryland: Culverton Company, 1965). Additional programs for three dimensional analysis of variance were provided by the same authors. The availability and use of the several computer programs of analysis of variance by Drs. Curtin and Warthen helped reduce the tedious series of statistical calculations into rapid processes, thus making successively finer comparisons of the data more feasible.

TABLE 2
CELL MATRIX

Sex	Aptitude Levels	Treatments	
B	1	I II III IV V	Legend: B = Boys G = Girls 1 = Low Ability 2 = Middle Ability 3 = High Ability I = Control II = Program III = Paced Program IV = Program Without Cues V = Program with Mixed Sequence
	2	I II III IV V	
	3	I II III IV V	
G	1	I II III IV V	
	2	I II III IV V	
	3	I II III IV V	

TABLE 3

RAW SCORES IN SECONDS BY CELLS*

BOYS

	I	II	III	IV	V
1	79.7	41.8	156.7	198.7	253.8
	134.4	08.0	07.1	267.0	331.7
	96.0	65.2	68.3	67.3	20.0
	118.6	33.2	47.7	09.1	509.2
	120.8	33.6	66.6	167.3	18.1
	468.0	20.0	158.2	25.6	16.6
	602.8	-02.5	82.8	11.2	254.7
	736.9	00.0	107.1	861.4	14.0
	131.2	70.7	02.6	Gave up	24.8
2	866.8	42.7	147.4	27.8	186.8
	504.0	06.9	20.8	56.5	267.2
	829.1	02.4	55.3	149.0	227.1
	333.9	47.3	20.3	19.5	22.1
	170.6	45.3	42.1	15.4	22.1
	55.5	-08.3	84.3	13.7	21.5
	64.6	02.5	16.4	33.9	19.1
	98.9	52.2	05.0	11.3	14.0
	48.4	64.2	26.8	07.3	36.7
3	619.9	66.8	90.1	41.0	-06.0
	129.1	11.7	05.8	31.8	10.7
	00.7	18.0	02.5	08.0	-01.8
	61.6	06.5	33.4	13.9	41.6
	25.0	04.7	30.4	57.8	10.0
	369.6	47.8	27.2	53.6	23.4
	282.5	24.6	72.4	22.3	15.8
	121.8	45.5	11.7	36.9	99.5
	Gave up	59.7	98.9	31.0	30.8

*"Gave up" and any score above 360.0 seconds was computed as 360.0 seconds.

Legend:

B = Boys
G = Girls

1 = Low Ability
2 = Middle Ability
3 = High Ability

I = Control
II = Program
III = Paced Program
IV = Program without cues
V = Program with mixed sequencing

TABLE 3
(Continued)
FAW SCORES IN SECONDS BY CELLS*
GIRLS

	I	II	III	IV	V
1	445.6	02.0	55.3	295.8	404.4
	430.6	19.1	112.2	323.8	35.9
	348.9	12.3	371.0	76.2	10.3
	290.7	50.7	156.1	103.5	173.0
	247.6	102.4	29.9	22.1	395.2
	171.0	202.6	137.6	08.4	234.1
	1311.0	-29.7	368.4	Gave up	136.2
	1274.0	134.1	25.3	Gave up	149.5
	Gave up	397.2	19.4	Gave up	Gave up
2	1055.4	85.5	16.0	299.0	1050.0
	89.5	207.1	67.8	156.5	131.6
	267.5	-04.5	106.3	30.0	167.1
	272.1	57.6	92.2	06.0	676.5
	797.5	03.8	15.2	20.2	514.7
	628.0	-03.2	05.6	09.9	91.6
	608.2	01.1	69.1	138.0	16.0
	669.2	46.1	135.8	111.8	296.0
	134.8	-09.5	74.3	16.5	03.6
3	900.0	29.5	34.4	21.0	08.9
	900.0	38.3	-02.1	15.4	18.2
	186.0	60.7	102.0	10.8	81.8
	124.0	54.7	-04.5	01.6	181.8
	185.6	64.8	38.3	25.4	108.1
	31.1	00.3	39.8	19.2	334.7
	306.7	124.6	-02.4	43.9	-01.5
	74.6	02.4	44.5	18.8	26.4
	287.8	33.8	31.0	14.9	12.5

*"Gave up" and any score above 360.0 seconds was computed at 360.0 seconds.

Legend:

B = Boys
G = Girls

1 = Low Ability
2 = Middle Ability
3 = High Ability

I = Control
II = Program
III = Paced Program
IV = Program without cues
V = Program with mixed sequencing

Since the data collected for this study were organized and analyzed by means of the analysis of variance technique, the writer considered the assumptions that underly the F test have been sufficiently met in this design.²

The alpha level of .05 was selected to test the statistical hypotheses of the treatment and the classification factors effects as a moderate approach to the investigation of significance. The F ratio, as an overall test of significance indicates whether or not significant differences are present in the totality of the groups submitted to analysis of variance.³ Further tests are needed "to see just where the significant differences are."⁴

Table 4 presents the mean of raw performance scores, together with the corresponding standard deviation and standard error of the mean for each of thirty cells. The cell identification is given in the left column. All cells have nine subjects.

Table 5 shows the results of the $2 \times 3 \times 5$ analysis. The five variations of the program by the three levels of ability by sex differences were significant for all three main effects at better than the .01 level.

²Joy P. Guilford, Fundamental Statistics in Psychology and Education, (New York: McGraw-Hill Book Company, 1965) pp. 301-302.

³Quinn McNemar, Psychological Statistics, (New York: Wiley and Sons, Inc., 1962) p. 285.

⁴Guilford, op. cit., p. 263.

TABLE 4

MEANS, STANDARD DEVIATIONS AND
STANDARD ERRORS OF THE MEANS

Cells			Mean	Standard Deviation	Standard Error of The Mean	Number in Cell
B	Lo	I	195.6	117.3	41.4	9
	M		205.7	136.5	48.2	9
	H		188.9	142.6	50.4	9
G	Lo	I	317.5	64.1	22.6	9
	M		234.8	99.6	35.2	9
	H		212.8	115.1	40.6	9
B	Lo	II	30.0	24.9	8.8	9
	M		28.3	25.4	9.0	9
	H		31.7	22.2	7.8	9
G	Lo	II	94.3	116.8	41.3	9
	M		42.6	66.1	23.3	9
	H		45.4	35.4	12.5	9
B	Lo	III	77.4	53.0	18.7	9
	M		46.4	42.2	14.9	9
	H		41.3	34.4	12.1	9
G	Lo	III	139.5	126.8	44.8	9
	M		64.7	42.1	14.9	9
	H		31.2	31.3	11.0	9
B	Lo	IV	160.8	137.5	48.6	9
	M		37.1	42.0	14.8	9
	H		32.9	15.7	5.5	9
G	Lo	IV	212.2	146.4	51.7	9
	M		87.5	93.1	32.9	9
	H		19.0	10.8	3.8	9
B	Lo	V	143.7	143.2	50.6	9
	M		90.7	98.3	34.7	9
	H		24.8	29.9	10.5	9
G	Lo	V	202.1	128.2	45.3	9
	M		198.4	139.8	49.4	9
	H		85.6	104.7	37.0	9
ALL			112.4	124.8	7.6	270

B=Boys
G=Girls

Lo=Low Ability Level
M=Medium Ability Level
H=High Ability Level

I to V = Program Treatments

The interaction of ability levels and program treatments was so close to significance at the .05 level that a step down was made to a two dimensional sex by program treatments contrast for each level of ability. The analysis of the low ability level by sex and program treatments (Table 6) shows significance for both sex and program treatments at the .01 level. The middle ability level also shows significance at the .01 level for sex and program treatments. (Table 7.) The analysis of the high ability level by sex and program treatments showed significance (.01) for program treatments only. (Table 8.) Since the difference between sex was insignificant at the high ability level, the sexes were combined and a one way analysis was run on the program treatments. The significance of difference remained well above the .01 level. (Table 9.)

Since the control treatment of the program did not give any instruction, it caused much of the variance. (See Table 4.) Therefore, the control group of cells was removed from the matrix of cells. a $2 \times 3 \times 4$ analysis was made (the four variations of the program: the program, the paced program, the program without cues and the program with mixed sequence, by the three levels of ability: low, middle, and high, by boys and girls.) Table 10 shows the results of this analysis.

Significance at the .01 level for all three main effects is indicated. However, there is also indicated an interaction between ability levels and program treatments significant at the .05 level. The drop down technique was again used to contrast each of the three ability levels by sex and the remaining four program treatments (the program, paced program, cueless program and the mixed sequence program.)

TABLE 5

ANALYSIS OF VARIANCE FOR THE TWO SEXES BY
THE THREE LEVELS OF ABILITY
BY FIVE TREATMENTS

Source of Variation	Degrees of Freedom	Variance	F Ratio	Significance of Difference
Sex	1	147939.3	15.47	.01
Ability Levels	2	167192.1	17.48	.01
Program Variations	4	296389.7	31.04	.01
Sex - Ability	2	18978.1	1.93	N/S
Sex - Program	4	9233.1	.96	N/S
Ability-Program	8	18218.2	1.90	N/S
Triple Interaction	8	2857.4	.29	N/S
Within Sets	240	9562.8		
Total	269			

TABLE 6

ANALYSIS OF VARIANCE OF THE LOW ABILITY LEVEL
BY SEX AND PROGRAM TREATMENTS

Source of Variation	Degrees of Freedom	Variance	F Ratio	Significance of Difference
Sex	1	115419.2	7.98	.01
Program Variations	4	100747.9	6.97	.01
Interaction	4	3671.3	.25	N/S
Within Sets	80	14447.9		
Total	89			

TABLE 7

ANALYSIS OF VARIANCE OF THE MIDDLE ABILITY LEVEL
BY SEX AND PROGRAM TREATMENTS

Source of Variation	Degrees of Freedom	Variance	F Ratio	Significance of Difference
Sex	1	65502.0	7.57	.01
Program	4	136239.4	15.76	.01
Interaction	4	7176.7	.83	N/S
Within Sets	80	8644.1		
Total	89			

TABLE 8

ANALYSIS OF VARIANCE OF THE HIGH ABILITY LEVEL
BY SEX AND PROGRAM VARIATION

Source of Variation	Degrees of Freedom	Variance	F Ratio	Significance of Difference
Sex	1	4974.3	.88	N/S
Program	4	96339.0	17.21	.01
Interaction	4	4100.1	.73	N/S
Within Sets	80	5596.3		
Total	89			

TABLE 9

ANALYSIS OF VARIANCE OF THE COMBINED SEXES OF THE
HIGH ABILITY LEVEL BY PROGRAM

Source of Variation	Degrees of Freedom	Variance	F Ratio	Significance of Difference
Program Variations	4	96339.0	17.45	.01
Within Sets	85	5518.5		
Total	89			

TABLE 10

ANALYSIS OF VARIANCE FOR TWO SEXES BY THREE LEVELS
OF ABILITY BY FOUR TREATMENTS (THE PROGRAM,
PACED PROGRAM, CUELESS PROGRAM AND
MIXED SEQUENCE PROGRAM)

Source of Variation	Degrees of Freedom	Variance	F Ratio	Significance of Difference
Sex	1	85422.6	10.41	.01
Ability Levels	2	160459.5	19.56	.01
Program Variations	3	62050.0	7.56	.01
Sex - Ability	2	10542.3	1.28	N/S
Sex - Program	3	7847.2	.95	N/S
Ability - Program	6	21334.8	2.60	.05
Triple Interaction	6	2998.0	.36	N/S
Within Sets	192	8201.3		
Total	215			

TABLE 11

ANALYSIS OF VARIANCE OF THE LOW ABILITY LEVEL BY
SEX AND THE FOUR PROGRAM TREATMENTS

Source of Variation	Degrees of Freedom	Variance	F Ratio	Significance of Difference
Sex	1	62746.5	4.03	.05
Program Variation	3	60451.4	3.88	.05
Interaction	3	147.0	.00	N/S
Within Sets	64	15545.3		
Total	71			

TABLE 12

ANALYSIS OF VARIANCE OF THE MIDDLE ABILITY LEVEL
BY SEX AND FOUR PROGRAM TREATMENTS (PROGRAM,
PACED, CUELESS AND MIXED SEQUENCE PROGRAMS)

Source of Variation	Degrees of Freedom	Variance	F Ratio	Significance of Difference
Sex	1	40897.9	6.02	.05
Program	3	41614.7	6.13	.01
Interaction	3	8382.5	1.23	N/S
Within Sets	63	6788.1		
Total	71			

The analysis of the low ability level (Table 11) shows significant differences at the .05 level for both sex and the remaining program treatments. The middle ability level indicates a difference significant at the .01 level for program treatments and a difference significant at the .05 level for sex (Table 12). However, at the high level of ability there was no significant difference for either sex or program treatments. (Table 13.) This analysis indicates that the performance of the high ability level is independent of sex and any of the program treatments. That is, the boys and girls in the high ability level are not significantly affected by mixing the sequence of the program or removing the cues or by group pacing. Therefore, no further analysis of the high ability level is necessary. The findings for the performance of the high ability level agree with the preponderance of previous research.

TABLE 13

ANALYSIS OF VARIANCE OF THE HIGH ABILITY LEVEL BY
SEX AND FOUR PROGRAM TREATMENTS (PROGRAM, PACED,
CUELESS AND FIXED SEQUENCE PROGRAMS)

Source of Variation	Degrees of Freedom	Variance	F Ratio	Signi- ficance of Dif- ference
Sex	1	2862.7	1.26	N/S
Program	3	2653.5	1.16	N/S
Interaction	3	5313.9	2.34	N/S
Within Sets	64	2270.5		
Total	71			

To identify the location of the program variations, a series of 2 x 2 contrasts (sex by the program itself versus each of the program variations) were made for each of the remaining two ability levels (middle and low).

Tables 14 and 15 show there was no significant difference (.05) between sexes or between the program and the group paced program for low and middle ability levels.

TABLE 14

ANALYSIS OF VARIANCE OF THE LOW ABILITY LEVEL BY SEX
AND THE PROGRAM VERSUS THE PACED VARIATION OF
THE PROGRAM

Source of Variation	Degrees of Freedom	Variance	F Ratio	Significance of Difference
Sex	1	35986.0	3.85	N/S
Program	1	19293.2	2.06	N/S
Interaction	1	12.0	.00	N/S
Within Sets	32	9333.8		
Total	35			

TABLE 15

ANALYSIS OF VARIANCE OF THE MIDDLE ABILITY LEVEL BY SEX
AND THE PROGRAM VERSUS THE PACED VARIATION OF THE PROGRAM

Source of Variation	Degrees of Freedom	Variance	F Ratio	Significance of Difference
Sex	1	2387.9	.93	N/S
Program	1	3640.1	1.50	N/S
Interaction	1	35.2	.01	N/S
Within Sets	32	2416.7		
Total	35			

Table 16 shows a significant difference (.01) between the program and the program with the cues removed at the low ability level. Table 17 shows no significant difference between sexes or program treatments at the middle ability level.

TABLE 16

ANALYSIS OF VARIANCE OF THE LOW ABILITY LEVEL BY SEX AND THE PROGRAM VERSUS THE CUELESS VARIATION OF THE PROGRAM

Source of Variation	Degrees of Freedom	Variance	F Ratio	Significance of Difference
Sex	1	30119.6	1.95	N/S
Program	1	139166.2	9.05	.01
Interaction	1	384.8	.02	N/S
Within Sets	32	15370.3		
Total	35			

TABLE 17

ANALYSIS OF VARIANCE OF THE MIDDLE ABILITY LEVEL BY SEX AND THE PROGRAM VERSUS THE CUELESS VARIATION OF THE PROGRAM

Source of Variation	Degrees of Freedom	Variance	F Ratio	Significance of Difference
Sex	1	9418.7	2.16	N/S
Program	1	6482.9	1.48	N/S
Interaction	1	2928.6	.67	N/S
Within Sets	32	4353.0		
Total	35			

The effect of sequencing is significant (.01) at both the low and middle ability levels. (See Tables 18 and 19.)

TABLE 18

ANALYSIS OF VARIANCE OF THE LOW ABILITY LEVEL
BY SEX AND THE PROGRAM VERSUS THE MIXED
SEQUENCE VARIATION OF THE PROGRAM

Source of Variation	Degrees of Freedom	Variance	F Ratio	Significance of Difference
Sex	1	33917.3	2.35	N/S
Program	1	110379.0	7.65	.01
Interaction	1	80.9	.00	N/S
Within Sets	32	14418.0		
Total	35			

TABLE 19

ANALYSIS OF VARIANCE OF THE MIDDLE ABILITY LEVEL
BY SEX AND THE PROGRAM VERSUS THE MIXED
SEQUENCE VARIATION OF THE PROGRAM

Source of Variation	Degrees of Freedom	Variance	F Ratio	Significance of Difference
Sex	1	33495.1	3.47	N/S
Program Variation	1	107070.7	11.11	.01
Interaction	1	19623.3	2.03	N/S
Within Sets	32	9634.3		
Total	35			

The findings for all the comparisons are summarized in Table 20.

A SUMMARY OF THE LEVELS OF SIGNIFICANCE FOR THE
FOREGOING SERIES OF ANALYSES OF VARIANCE

Ability Levels	All	Low	Middle	High	High	All	Low	Middle	High
Design	2x3x5	2x5	2x5	2x5	1x5	2x3x4	2x4	2x4	2x4
Sex	.01	.01	.01	N/S	--	.01	.05	.05	N/S
Ability Levels	.01	--	--	--	--	.01	--	--	--
Program Treatment	.01	.01	.01	.01	.01	.01	.05	.01	N/S
Sex - Ability	N/S	--	--	--	--	N/S	--	--	--
Sex - Program	N/S	N/S	N/S	N/S	--	N/S	N/S	N/S	N/S
Ability - Program	(.05)	--	--	--	--	.05	--	--	--
Triple Interaction	N/S	--	--	--	--	N/S	--	--	--

2 x 2 DESIGNS (CONTRASTS WITH THE PROGRAM)

Program Treatment	Group Paced	Cueless	Mixed Sequence
Ability Levels	Low	Middle	Low
Sex	N/S	N/S	N/S
Program Treatment	N/S	.01	.01
Interaction	N/S	N/S	N/S

Legend: Sex Boys Girls

Ability Levels: Low Middle High

Program Treatments: I Control II Program III Paced Program IV Cueless Program V Mixed Sequence

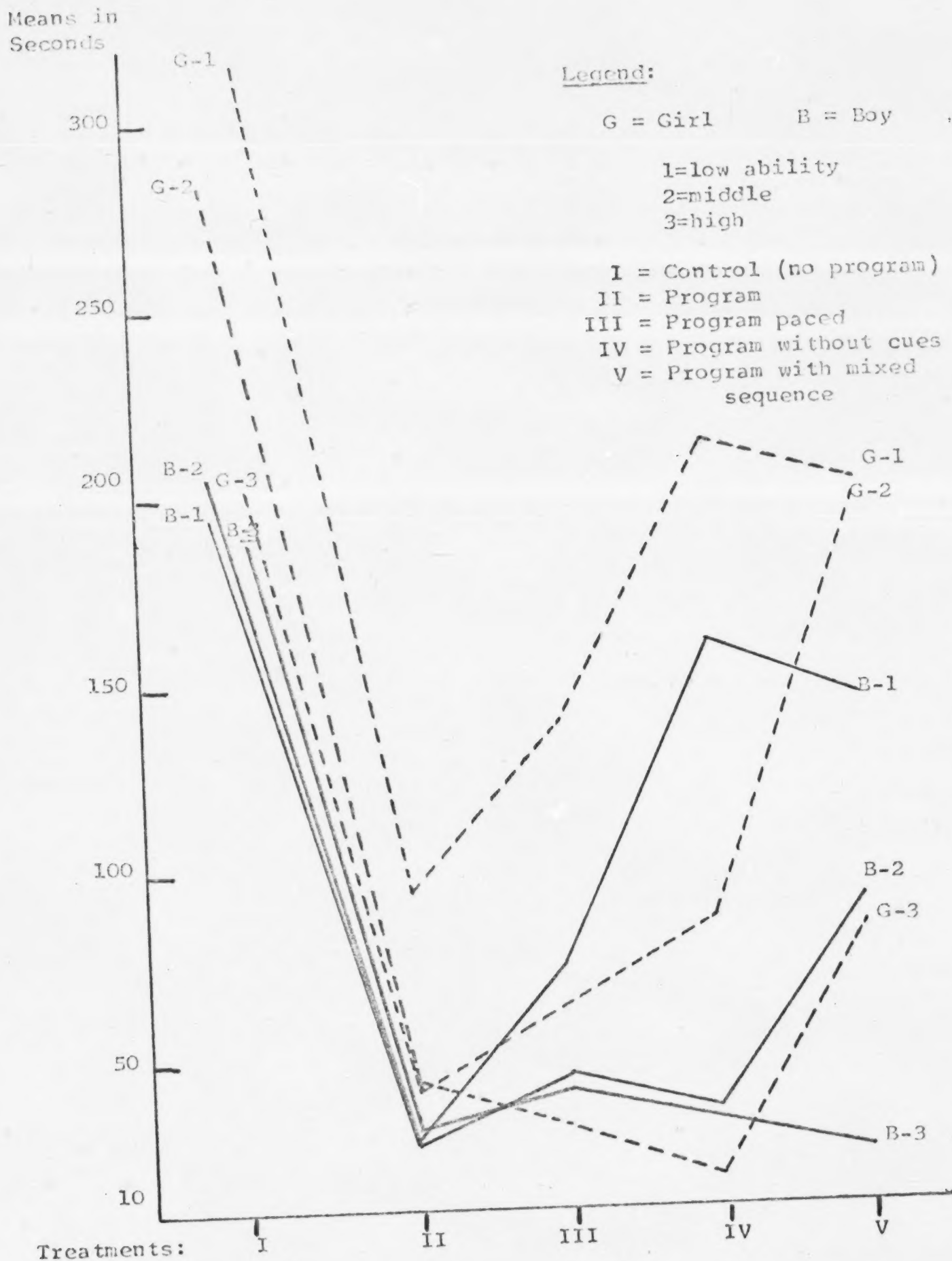
5 Treat.=I to V
4 Treat.=II to V

The plotting of the means of the cells in this research design offers another way of looking at the data involved. In these plots the lower the time the better the score is. (See Illustration No. 8.) This shows all the means plotted by sex and ability level over the five program treatments. The lines connect each sex versus ability level and are so labeled at each end of the line.

Illustration No. 9 shows the same data plotted by sex and program treatment over the three levels of ability. In both Illustration Nos. 9 and 10 the relatively large differences caused by the control group is obvious. In Illustration No. 10 the non-significant differences among the remaining program treatments in the high ability level is evident.

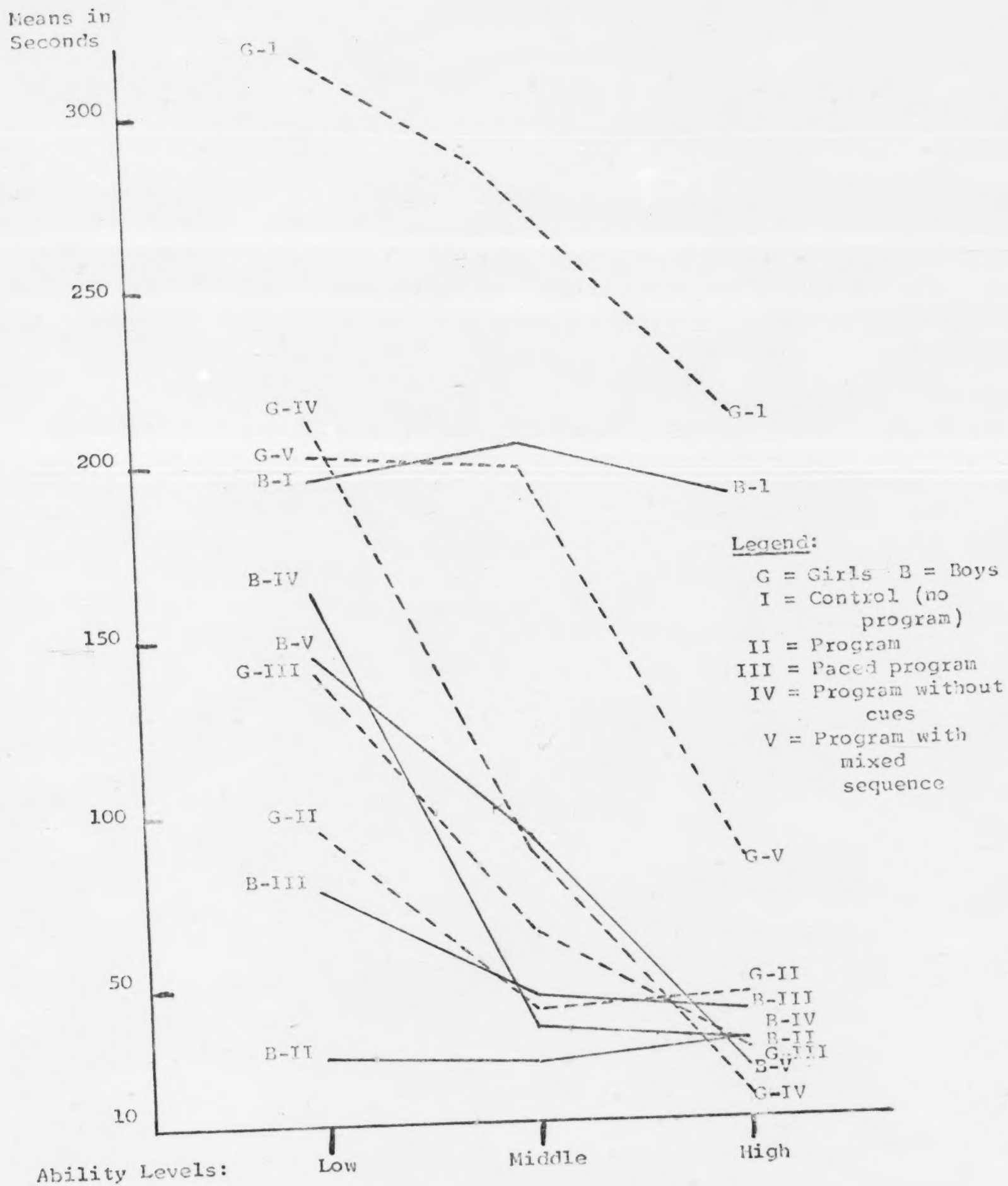
The following plots are arranged to compare the similarity in trends in the comparison of the program treatment with the effects of mixed sequencing, removal of cues and the use of group response (group pacing) in that order. The significant differences will be obvious. And, granting a difference in magnitude, there is also an obvious similarity of the trends of the plotted means in Illustration No. 11 through No. 16.

ILLUSTRATION NO. 8



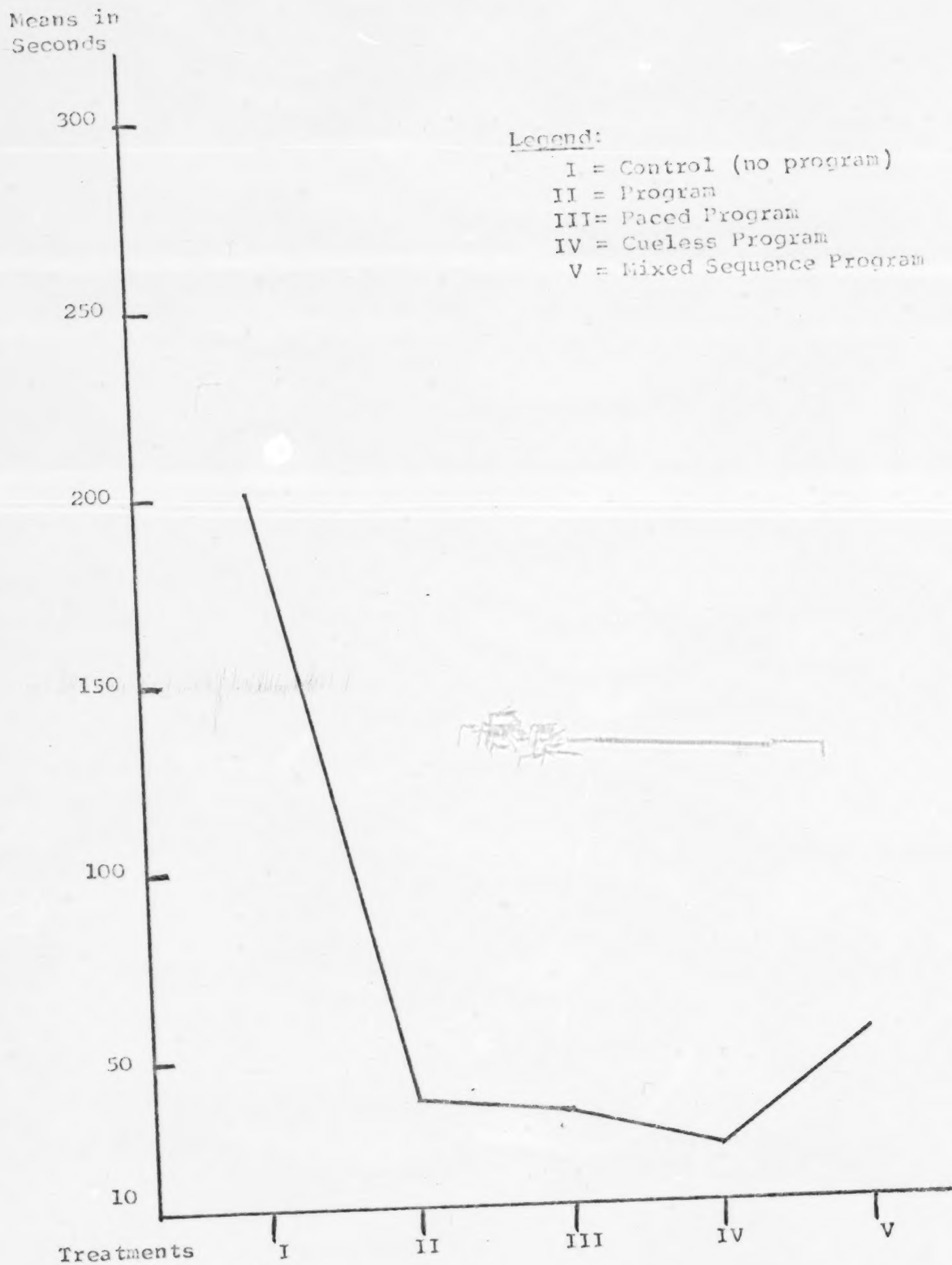
Comparison of the Three Ability Levels By Sex
Over The Five Variations of the Program

ILLUSTRATION NO. 9



Comparison of the Five Variations of the Program
By Sex Over Three Levels of Ability

ILLUSTRATION NO 10



Comparison of High Ability Level by Combined Sex
Across the Five Treatments

Mixed Sequencing

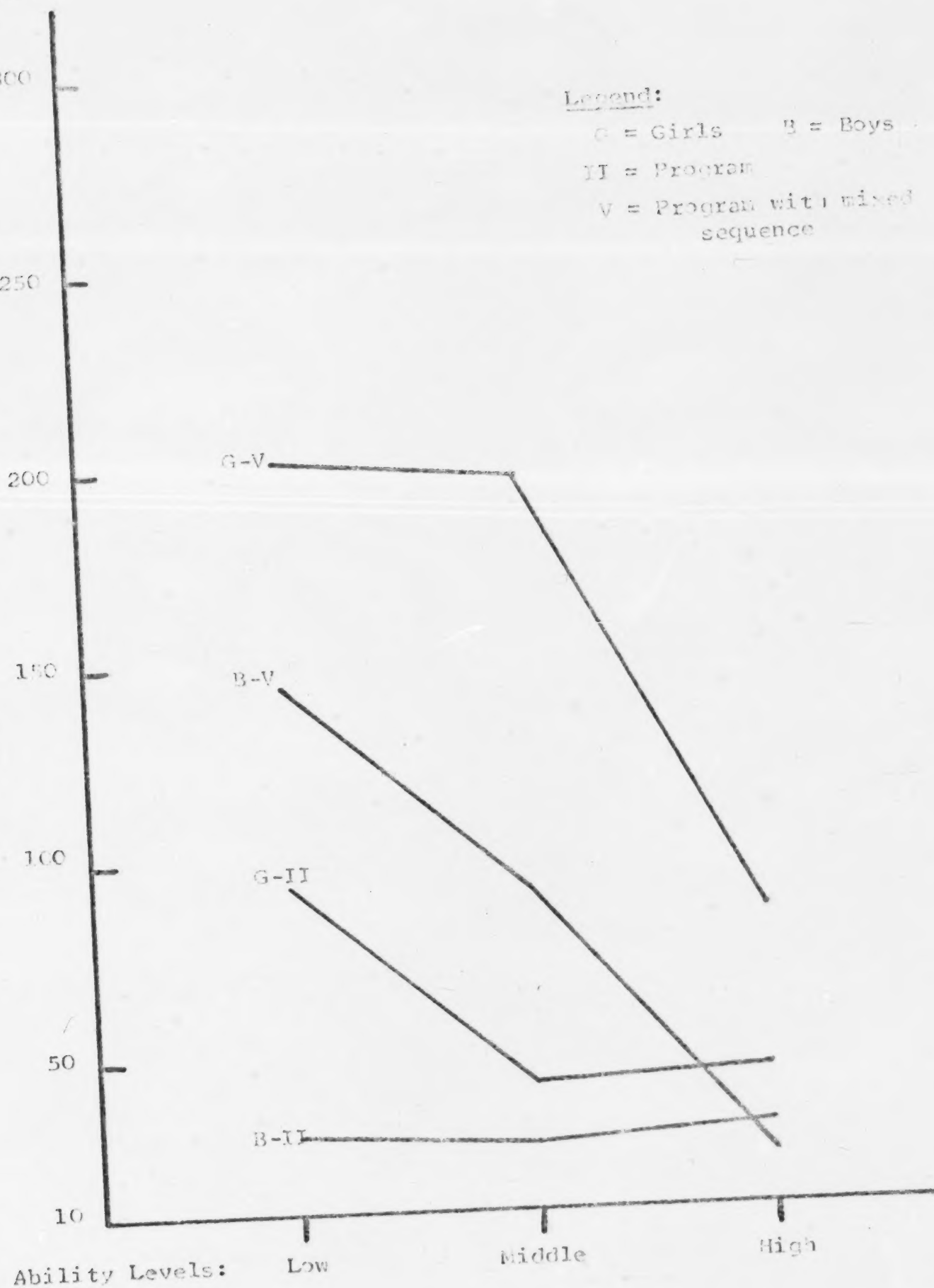
Illustration No. 11 compares the means of the scores of the boys and girls in the mixed sequence program and the program by ability levels. The ability of the high level cells to overcome the effect of mixed sequencing is graphically illustrated as is the impairment to learning for the two lower groups caused by mixing the sequence. Note also that the high level boys in the mixed sequencing cell did better than any of the program cells. The mean score of their cell was the second highest.

Illustration No. 12 compares the boy and girl means of the program and the mixed sequence variation by ability levels. Note the gap which depicts the significant difference for the middle and low ability levels who had the mixed sequence variation of the program. Note also the closeness of the means of the high ability level cells that had the mixed sequence program to the means of the low ability level cells that had the program.

ILLUSTRATION NO. 11

Means in
SecondsLegend:

G = Girls B = Boys
 II = Program
 V = Program with mixed
 sequence



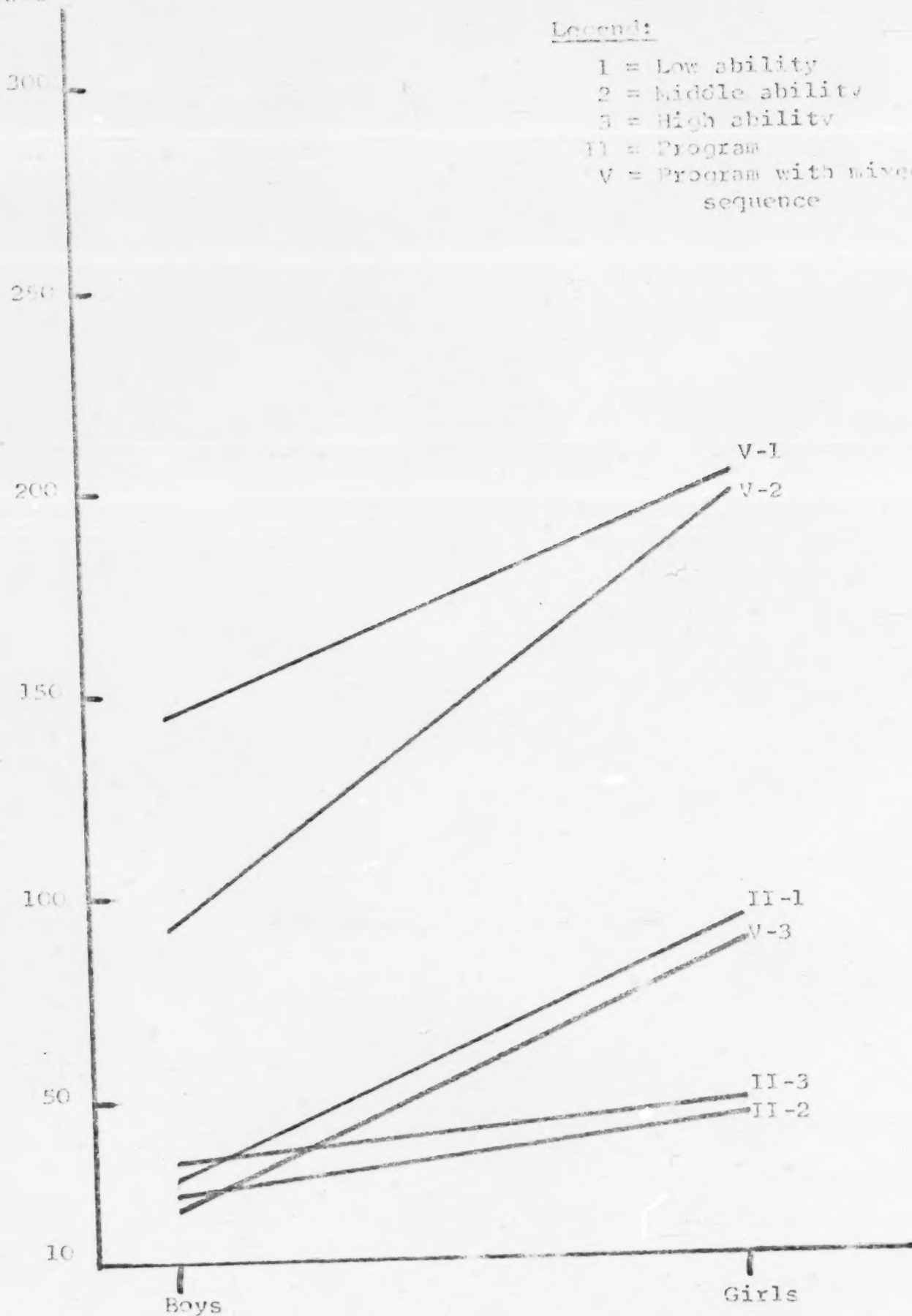
Comparison of Program and Program with mixed sequence by
 Sex Over the Three Levels of Ability

ILLUSTRATION NO. 12

Means in
SecondsLegend:

- 1 = Low ability
- 2 = Middle ability
- 3 = High ability

II = Program

V = Program with mixed
sequence

Comparison of the Program and the Program
With Mixed Sequence Over Sex

Cueing

Illustration No. 13 shows the relationship of cell means of the program treatment and the cueless treatment. The lower levels of ability of both boys and girls who had the cueless version of the program have relatively long times (poor scores). However, this decrement is almost entirely made up at the middle level of ability. As a group the high level ability girls in the program with the cues removed had the best mean score, even better than the high level boys and girls in the normal program and better than the high level ability boys in the mixed sequence who had the second best mean score.

Illustration No. 14 shows the large difference between the low level ability boys and girls in the program without cues and the remaining cells in the comparison of the cueless and the normal programs.

ILLUSTRATION NO. 13

Means in
Seconds

300

Legend:

G = Girls

B = Boys

II = Program

IV = Program without cues

250

200

G-IV

150

B-IV

100

G-II

50

B-II

10

Ability Levels:

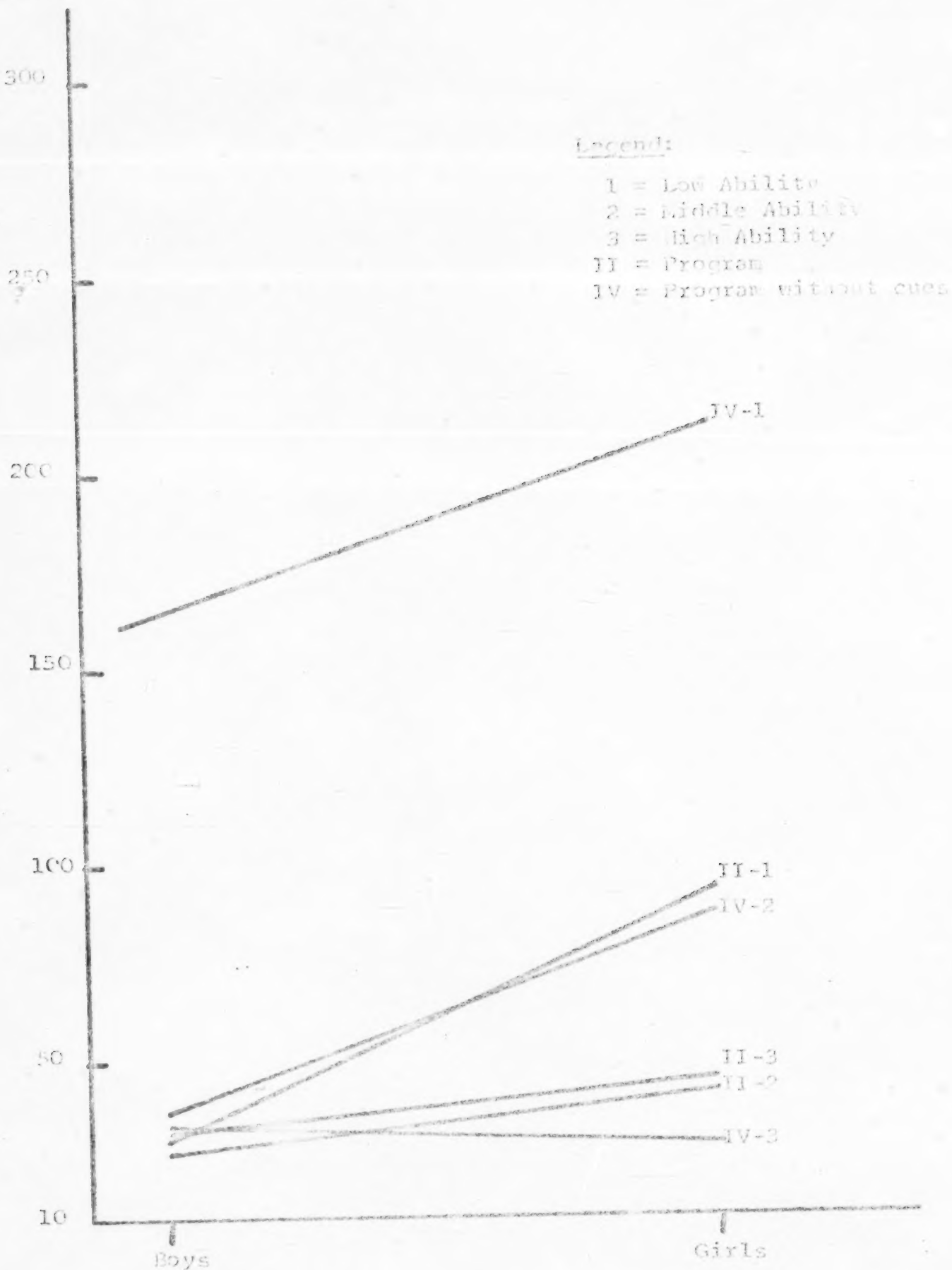
Low

Middle

High

A Comparison of the Program and the Program without Cues
By Sex Over the Three Levels of Ability

ILLUSTRATION NO. 14

Means in
Seconds

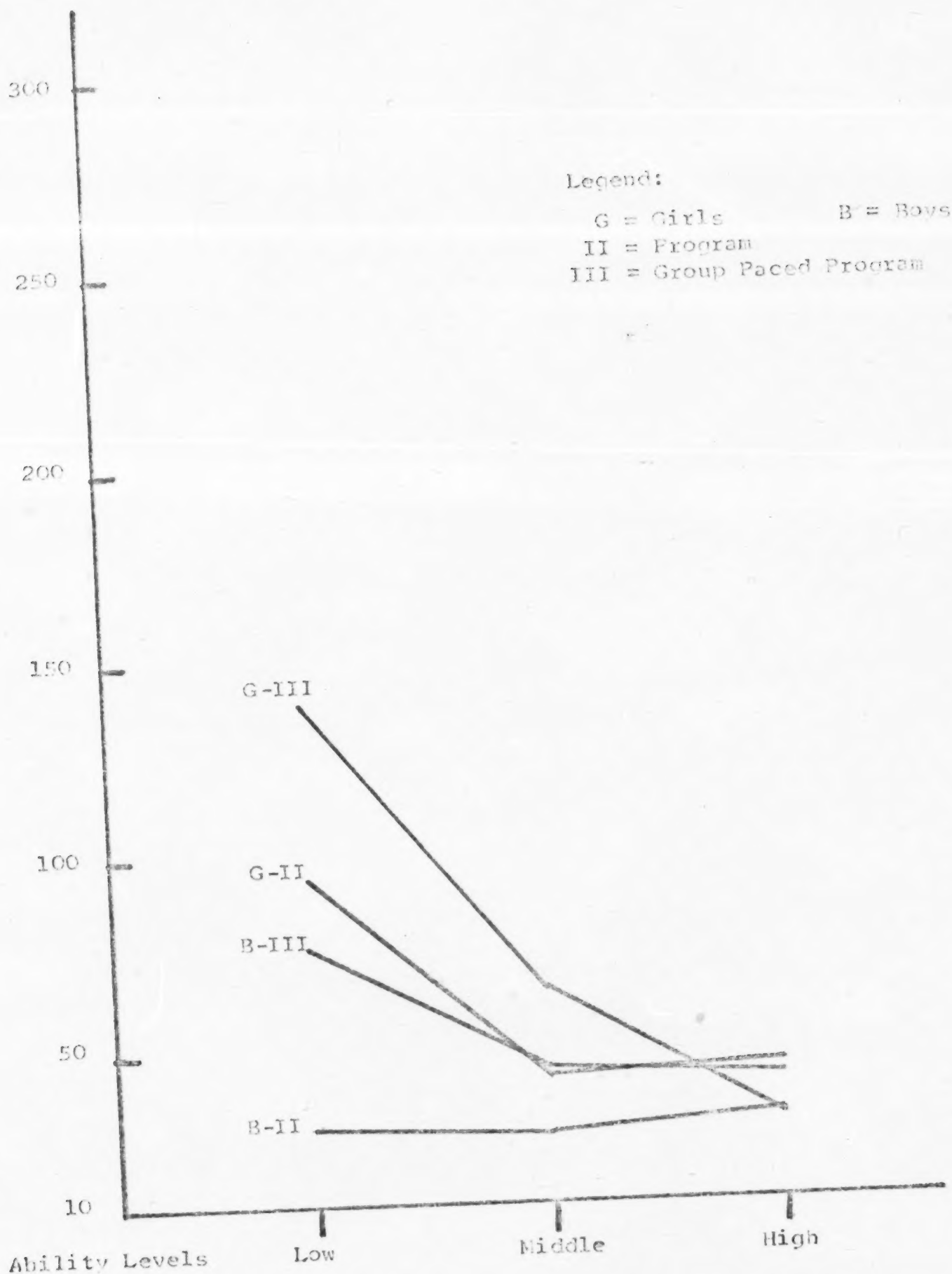
Comparison of the Program and the Program Without Cues
By the Three Levels of Ability Over Sex

Group Pacing

The next comparison was between the normal program which was pursued on an individual basis and a group paced version of the program. The writer paced the subjects through the program and allowed only vicarious interaction with the learning materials and group response instead of the physical interaction and individual response allowed in the other versions of the program.

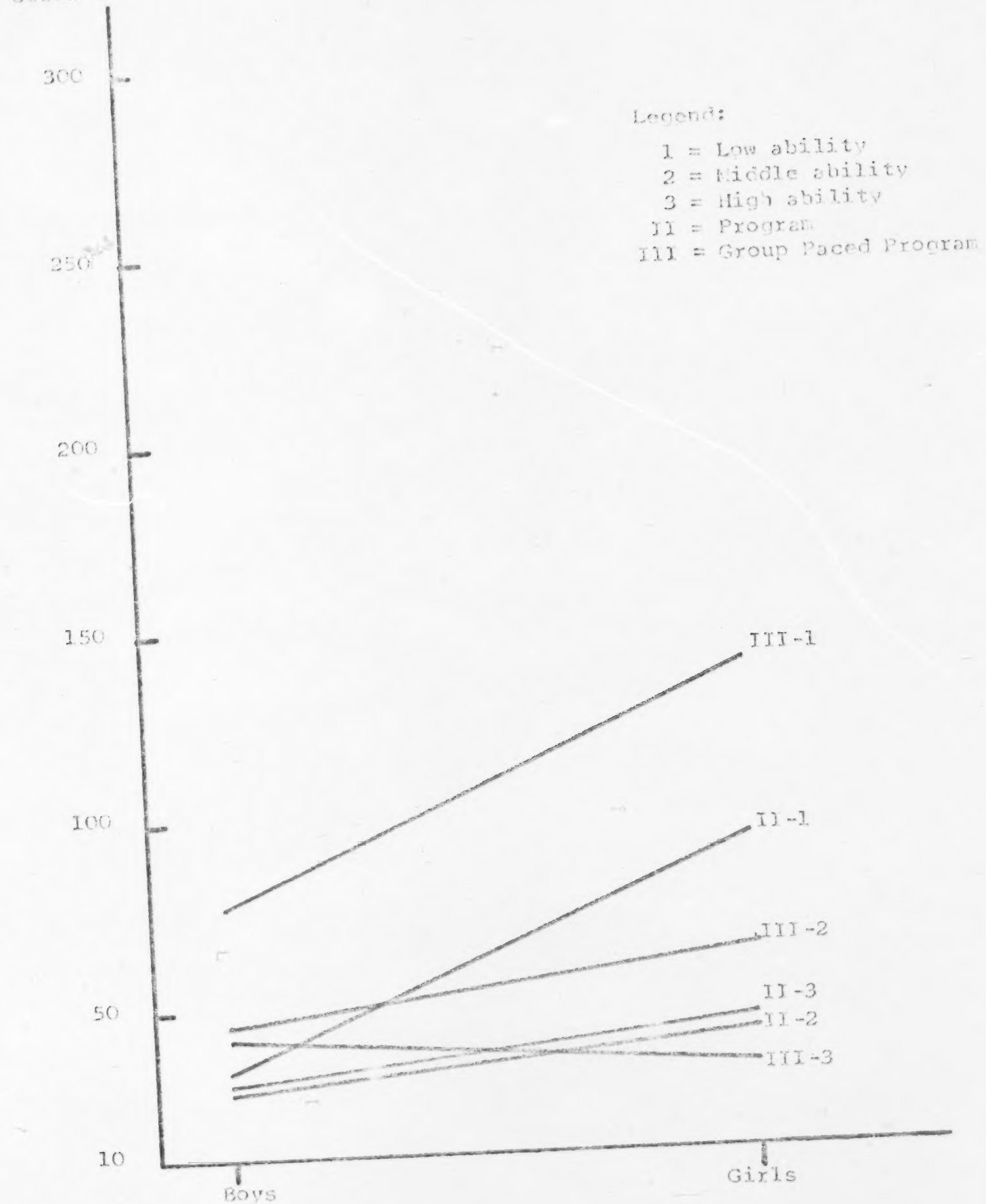
While there was no significant differences at any ability level between the program and the paced program, plottings of these contrasts are included for comparison with the cueless and mixed sequence versions with the program. The following phenomena is pointed out as a pertinent part of this study. A comparison of Illustration No. 15 with Illustrations Nos. 11 and 13 shows a great deal of similarity in the trend of the lines even though the magnitude of space between them (difference) is not the same. A comparison of Illustration No. 16 with Illustrations Nos. 12 and 14 also points up the similarity of the relative position of the lines connecting low level ability boys and girls in these variations.

ILLUSTRATION NO. 15

Means in
Seconds

Comparison of the Program and the Group Paced Program by
Sex Over the Three Levels of Ability

ILLUSTRATION NO. 16

Means in
Seconds

Comparison of Program and Group Paced Program By Each
Level of Ability Over Sex

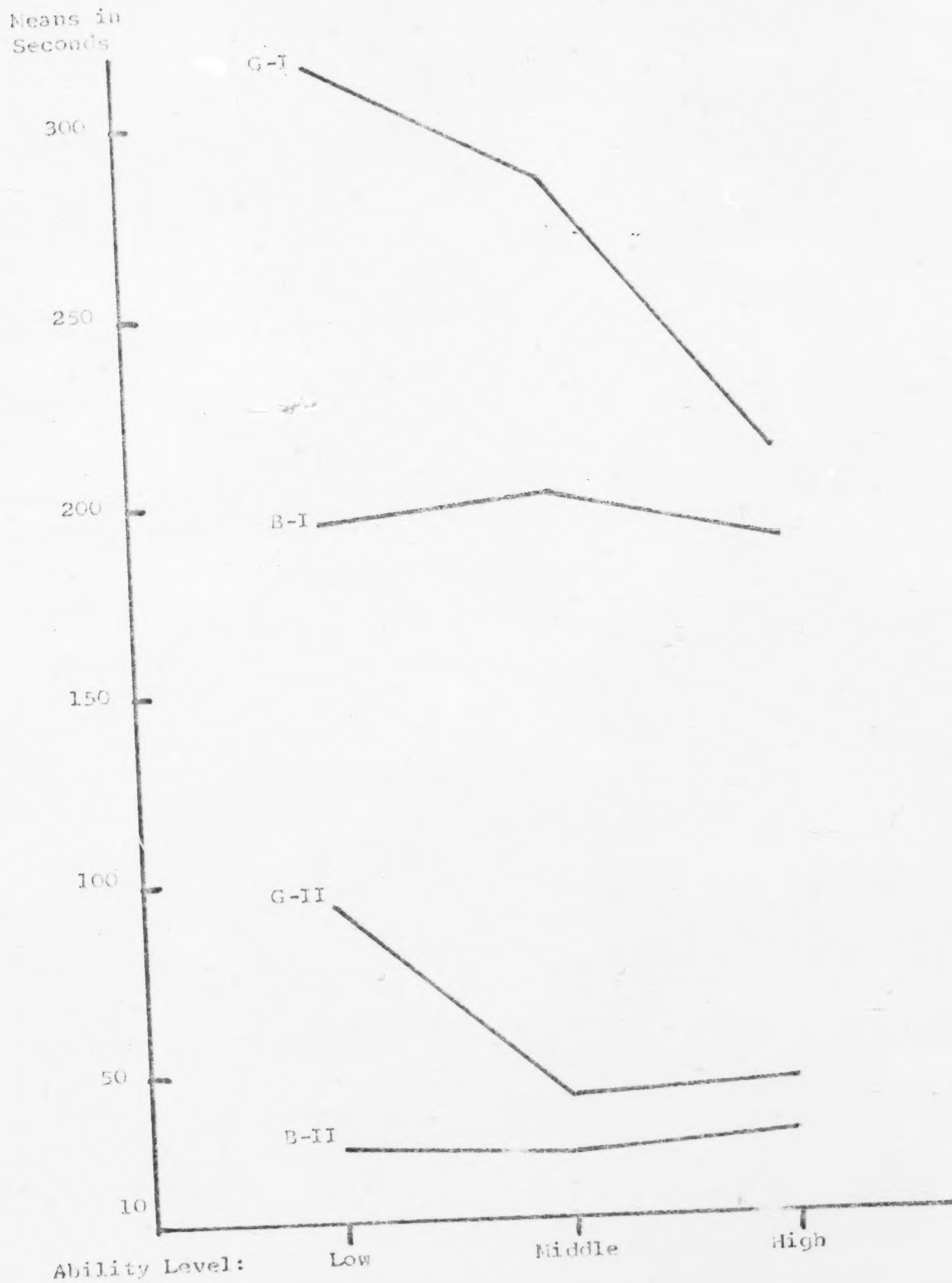
Control

The nature and the brevity of the program lead to questions about its effectiveness. Question may be raised as to whether the program designed by the writer actually contributed to a learning process. Likewise, question may be raised as to its relative efficiency. The major differences between the control and the program groups indicate a degree of improvement under the program condition which may be accepted as evidencing learning. Considering the only other known similar types of programs--the variations of the program--the program shows evidence of being both more effective and more efficient.

Illustration No. 17 shows the wide difference in the program and the control group inferred in the analysis. It also depicts a striking similarity in the flatness of the line connecting the mean scores for boys in both the program and the control group.

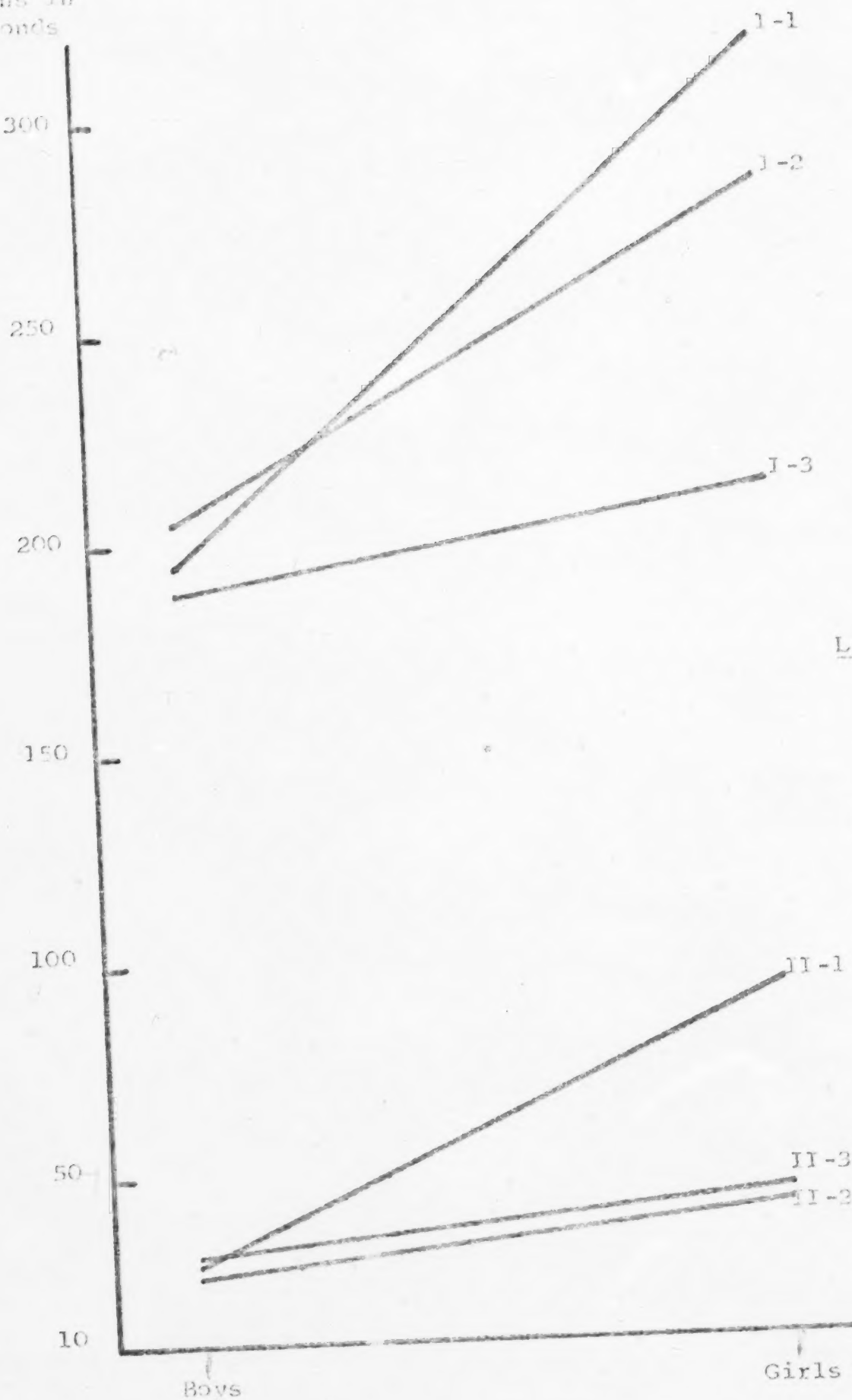
Illustration No. 18 indicates not only the increasing difficulty that each lower ability level of girls had with this type of problem solving but also the similarity in slopes of the lines connecting the means of the high ability level of boys and girls in both the control group and the program group.

ILLUSTRATION NO. 17



Comparison of Control (No Program) By Sex Over the
Three Levels of Ability

ILLUSTRATION NO. 18

Means in
Seconds

Legend:

- 1 = Low ability
- 2 = Middle ability
- 3 = High ability
- I = Control (No program)
- II = Program

Comparison of Control (No Program) and Program By the
Three Levels of Ability Over Sex

Summary

Two hundred and seventy raw scores of subjects divided into three ability levels by sex and randomly assigned to five program variations were analyzed for variances through a series of designs that reduced the factors from a $2 \times 3 \times 5$ to a 2×5 , to a $2 \times 3 \times 4$, and then to 2×2 designs. All main effects were significant at the .01 level of confidence in the $2 \times 3 \times 5$ design. Much of this difference was built in by the use of a control group. The control group was removed from the data matrix and a $2 \times 3 \times 4$ design was analyzed for variance.

In this analysis the three main effects indicated differences significant at the .01 level. However, interaction between ability levels and program treatments reached significance at the .05 level. In the 2×4 (sex by program) analysis of the high ability level there was no significance (.05) for either sex or program treatment. Therefore, the performance of the high ability level was independent of sex differences and program variations.

In a series of 2×2 analysis the following was found:

There was no significant (.05) difference between the group paced program and the program.

The difference between the cueless program and the program was significant (.01) for the low ability level.

The difference between the mixed-sequenced program and the program was significant (.01) for both the middle and low ability levels.

The data from the analyses and the graphs of the relationships

of the means show a lessening ability to profit from a program with mixed sequence or removed cues as the ability level goes down.

CHAPTER IV

INTERPRETATION, CONCLUSIONS AND SUMMARY

The purpose of this study was to investigate the effect of group pacing, cueing and sequencing on programmed instruction. The preponderance of research in these areas found no significant differences when programs were varied by group pacing, removing cues or mixing the sequence. None of the research designs seemed to address adequately the question of individual differences within a normal distribution of learners. The seventh grade level was chosen for this study in order to use a normal learner distribution before it was seriously affected by dropouts. A program consisting of seven block designs was developed specifically for the seventh grade level. An entire seventh grade class of 424 pupils made up the initial pool of subjects. Due to matching by sex and aptitude plus absences, the number of criterion problem scores computed was 270. These were the scores of pupils who were randomly assigned across the five treatments by sex and three ability levels. The five treatments were: I. Control (no program), II. The Program, III. The group paced program, IV. The cueless program, and V. the mixed sequence program. A series of computer programmed multiple analyses of variance were used to refine the analysis of the data to the point where it could test all of the following hypotheses:

- H_{1A} : Performance on the criterion problem will be affected by the variations in the program.

- H_{1B} : Performance on the criterion problem will rank in the following descending order:
1. The program.
 2. The paced program.
 3. The cueless program.
 4. The mixed sequence program.
- H_{1C} : Performance on the criterion problem will be least affected by program variations in the high ability level.
- H_{1D} : If performance on the criterion problem for any one level of ability is adversely affected by one of the variations in the program, then the performance of any lower ability levels will also be adversely affected by the same program variation.
- H_{2A} : Performance on the criterion problem will be affected by the ability levels.
- H_{3A} : Performance on the criterion problem will be affected by sex.
- H_{3B} : The performance of the boys on the criterion problem will exceed that of the girls.
- H_{3C} : The sex difference in performance on the criterion problem will be least at the high ability level.

These research hypotheses have been tested through analyses of the scores of the criterion problem. In the organization of this data for evaluation by analysis of variance, the main elements of the design were the program treatments. Ability levels and sex were used as classification factors. This provided a 2 x 3 x 5 design (sex by three levels of ability - high, middle and low - by five program treatments - control, program, paced, cueless, and mixed sequence programs.) A multiple factor analysis of variance for three dimensions, different subjects with equal subclass frequencies, fixed model by a least squares solution was used to analyze the 2 x 3 x 5 design and a subsequent 2 x 3 x 4 design (sex

by the ability levels by program treatments minus the control). A similar analysis of variance for two dimensions were used for subsequent 2×5 , 2×4 and 2×2 designs. The 2×5 design was sex by the five treatments for each level of ability. The 2×4 design was sex by the treatments minus the control for the low and middle levels of ability. Since the 2×5 design had shown sex was not significant at the high level of ability, a 1×4 design of a one dimension analysis of variance was used at the high level of ability. The 2×2 designs separately contrasted the paced program, the cueless program and mixed sequence program with the program itself for the low ability level and for the middle ability level. The .05 alpha level was used to evaluate the significance of results. Table 20 in Chapter III summarizes these results.

Evaluation of Relevant Research Hypotheses

The first hypothesis (H_{1A}) that performance on the criterion problem will be affected by the variations in the program is accepted in part. While the analyses in the larger designs (see Tables 5, 6, 7, 8, 9 and 10) show significant differences, a look at the 2×4 designs in Tables 11 and 12 show that differences in program variations are significant for the low and middle levels of ability. Table 13 shows that the affect of program variation is not significant at the high ability level. Therefore, hypothesis H_{1A} is accepted for the low and middle levels of ability and it is rejected for the high level of ability.

The second hypothesis (H_{1B}) is that performance on the criterion problem would rank in the following descending order: 1. The

program, 2. The paced program, 3. The cueless program, and 4. The mixed sequence program can be accepted in part. The plots of the means, Illustrations 8 and 9, show that the trend does in this manner. However, it can only be established with statistical confidence (.01) that the cueless program will differ from the program itself at the low ability level and that the mixed sequence program will differ at both the low and middle levels of ability. (See Tables 14 through 19.) Therefore, hypothesis H_{1B} is completely rejected for the high ability level and is rejected for the ranking of the program over the paced program variation but is accepted for the ranking of program, the cueless program and the mixed sequence program.

The third hypothesis (H_{1C}) that performance on the criterion problem would be least affected by program variations in the high ability level is accepted. The one dimension (2×4) analysis of the four program treatments (minus control) shows (Table 13) no significant difference at this level.

The next hypothesis (H_{1C}) that, if performance on the criterion problem for any one level of ability is adversely affected by one of the program variations, then the performance of any lower ability levels will also be adversely affected by the same program variation is accepted. This hypothesis is acceptable because the mixed sequence program variation caused a difference from the program significant at the .01 level for the middle ability level and a difference significant at the .01 level for the low ability level. (See Tables 18 and 19.)

The fifth hypothesis (H_{2A}) that performance on the criterion

problem would be affected by the ability levels was not established because of the interaction between ability levels and the program treatments minus the control treatment. (See Table 10.) Illustrations 8 and 9 depict these interactions.

The hypothesis (H_{3A}) that sex affects performance on the criterion problem is acceptable in part. In the $2 \times 3 \times 5$ and the $2 \times 3 \times 4$ analyses the main effect for sex was significant at the .01 level. (See Tables 5 and 10.) The 2×5 and 2×4 analyses for the low and middle levels of ability show significance for sex. (See Tables 6 and 7, 11 and 12.) However, the 2×5 and 2×4 analyses for the high level ability indicate no significant difference. Therefore, H_{3A} is acceptable for the low and middle levels of ability but is rejected for the high ability level.

The same rationale as that used for hypotheses (H_{3A}) was used for hypothesis (H_{3B})^{which} was accepted for the low and middle levels of ability but was rejected for the high ability level.

To briefly sum up hypotheses H_{3A} and H_{3B} , sex difference on the performance of the criterion problem depended on ability level.

The analyses in Tables 8 and 13 showed that the sex factor was not significant at the high level of ability. Therefore, the last hypotheses, H_{3C} , that sex difference in performance on the criterion problem would be least at the high ability level must be accepted.

Conclusions

The series of analyses that are given in the previous chapter show that, in a program which was specifically developed for the grade level of the subjects, the mixing of the sequence or the removal

of cues caused significant (.01) decrements in the criterion test scores. More pertinent to our study, these decrements occurred in the lower and middle ability level while the high ability levels were unaffected by the above mentioned program variation. While a sex difference reached significance only in the overall analyses (see Table 20 on page 69), the plottings of the means in Chapter III clearly show that girls do not do as well as boys at the lower ability levels. However, this difference disappears at the high ability level. (See Illustration No. 20.)

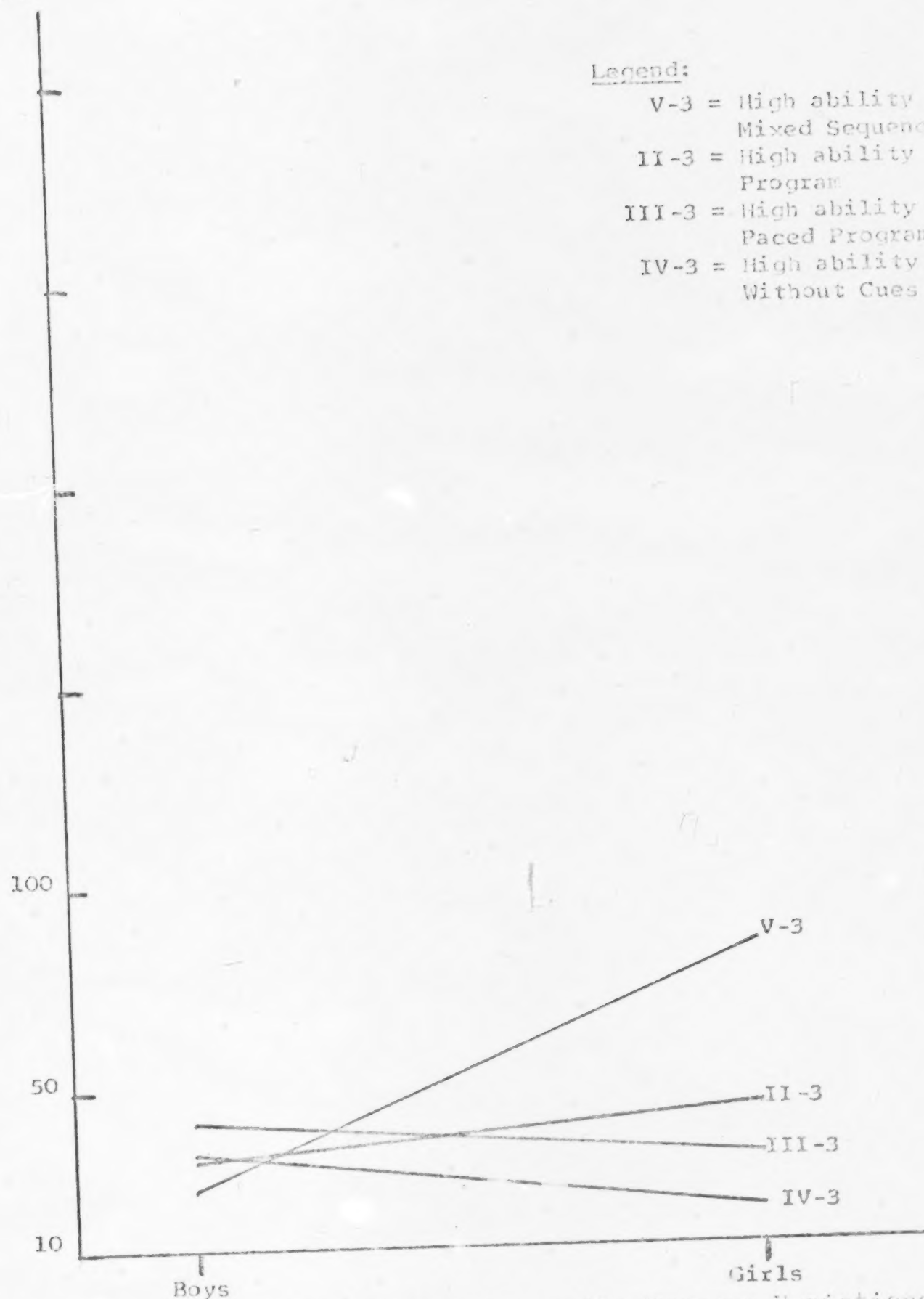
A comparison of the effects of mixed sequence in which only high ability level subjects were used would give information that is misleading. This is vividly pointed out in the further analysis of the cells within this comparison. The results of these analyses and the graphic illustrations show that the middle and lower ability levels were drastically affected by the mixing of the sequence (.01) whereas the high ability level was unaffected. There was only a slight non-significant decrement (caused by three comparatively poor individual scores) in the high ability level girls' mixed sequence cell. In brief, some factor such as the cognitive ability mentioned in Chapter I seems to enable the high ability level to effectively assimilate the learning content even when it is received in disordered fashion.

The comparison between the program and the cueless version of the program presents data somewhat similar to that of the previous comparison with the mixed sequencing variation. When the analysis is reduced to a 2 x 2 comparison of cells, a significant decrement

ILLUSTRATION NO. 20

Means in
SecondsLegend:

- V-3 = High ability level
Mixed Sequence
II-3 = High ability level
Program
III-3 = High ability level
Paced Program
IV-3 = High ability level
Without Cues



Comparison of High Ability Levels on the Program Variations Over Sex

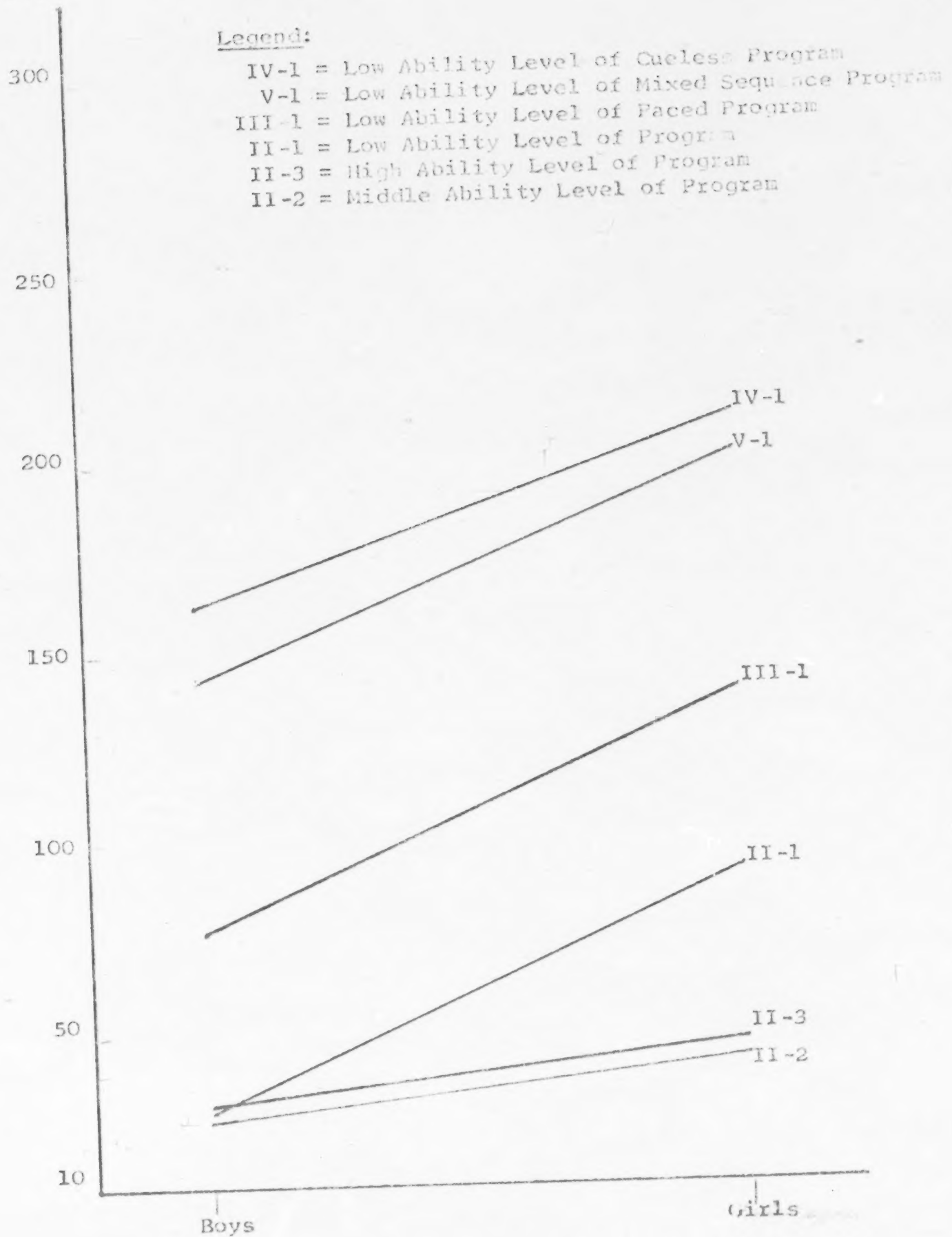
(.01) is found between the scores in the low ability level. Again the high ability levels had little difficulty in assimilating the concepts.

There is an arresting aspect to the non-significant comparison of the program to the paced version of it. There is a noticeable similarity in the trend of decrement that appears in the plotting of the means. In this treatment there were the laboratory atmosphere benefits of novelty, of holding the subjects' attention and of fostering involvement of the individual as a member of a group. These circumstances might not occur in the routine day-to-day relationships with a familiar teacher. Considering situations where attention and individual involvement might be less, it seems fair to assume that this similar trend might also approach the magnitude of the trends of the other two variations. If this happened, the lower ability levels would be most affected. (See Illustration No. 21 on page 96.) Bearing in mind that the effectiveness of group pacing techniques depends so heavily on holding each individual's attention even though the individual is both going at a rate not necessarily his own and is often not required to interact with or respond to the learning material, we should be cautious about the findings on group pacing in this study. In more routine uses of group pacing there might be significant decrement in the performance of the lower ability level.

For whatever aspects and range of learning this study applies, the following observations are offered:

Since program variations did not affect the high ability levels, these levels seem to have a cognitive ability to organize the concepts involved in the learning exercise. Therefore, a more concise learning

ILLUSTRATION NO. 2

Means in
Seconds

Comparison of Low Ability Levels on the Program Variations Over Sex

process than the program might be more efficient for those who already have this ability. However, the program seemed precisely appropriate to the boys in the lower ability level. Yet it was not as appropriate for the girls at the low ability level. (See Illustration No. 31.) An enriched program might be more suitable for these girls.

Programmed instruction would seem to be most effective in learning situations where the cognitive ability is unable to foster the unaided understanding of the concepts involved. The techniques of programmed instruction will be effective in relation to the degree that a given program is carefully and precisely developed for learners who do not possess the cognitive ability to readily order and assimilate the material to be learned. For instance, a program might help most beginners in attempting to build a radio, to assemble a television set or to develop an initial orientation to the studies of epistemology, psychology or geology.

The variance in raw scores in Table 3 and the error of the mean column in Table 4 indicates that grouping by mental ability is a rather crude manner of establishing homogeneous groupings in criterion performance. This post hoc inspection of the scores indicates that factors other than the measured mental ability, sex or treatment were affecting the scores. The use of some pre-entry test on content might have allowed better development of cell homogeneity.

The findings of this study also indicate that a certain amount of caution must be used when designing and interpreting research on human learning. The kind of information found in the typical one dimensional analysis without sufficient control factors is at best

not restricted to the educational technologist and at worst may be misleading in order for the following reasons:

1. At such a gross level of analysis, the significance or lack of significance may only indicate how fortunate or unfortunate the effect of unknown variables was.
2. The typical one dimensional analyses indicate only what is happening to the groups as wholes. There is too great a danger that results from these one dimensional comparisons will be translated into some rigid rule that will be applied to every learner who is represented in the overall group. In other words, what applies to the "average" learner might be applied to each and every learner in the total group as if the variables affecting one type of learning situation were constant for all learners in all learning situations. For instance, almost all the extant research on the effects of mixed sequencing found no significant differences and yet this study indicates that these previous findings are far from so for lower ability learners.

In regard to the first reason above, experiments concerning human learning involve a highly mobile, dynamic and extremely complex variable in man as a learner. A perfectly controlled experiment with such complex organisms would seem to be a virtual impossibility and even well controlled ones a rarity. If a high level of confidence requirement forecloses any investigation of trends such as those found in the graphic illustrations in Chapter III, then we

may be losing important information that--taken in some cumulative form--could be extremely relevant to an increase in our knowledge of the learning process.

And in regard to the second reason, if caution is not used in applying the results derived in relation to a gross average learner, the applicability will get less relevant to the needs of each individual learner as his individual situation moves away from that of the average learner. Concern for individual differences among learners must be translated into research designs in order to learn more about aiding the individual learner. The effect of other variables in the learning situation must be examined in the light of how they influence learning effectiveness at the individual learner's level of ability in a particular kind of learning. We should at least use multiple levels of learner ability measured not only by standards of general ability but also by some manner of pre-entry testing of the individual learner aptitude precisely in the type of material to be learned. Using the findings of this study, for example, a concern for sex difference in the solution of block design problems would be justified for the low ability levels but would have little justification for the high ability levels. The comparison of results of the three levels of boys in the control group with the three levels of boys in the program (see Illustration No. 17 on page 24) provides a remarkable insight into the relative effectiveness of a specifically designed program when the entry level of each learner is roughly the same (assuming for the moment that the mean scores of each of these cells is representative of the performance of each member in a cell).

The gain from all three of the means of the boys in the control group to the three means of the boys who had the program is almost identical. This comparison indicates that this program was ideally designed for effectiveness in this grade level of boys. However, an inspection of the same illustration shows that this program needs enrichment for low ability level girls. However, this trend does not reach significance at the .05 of confidence and therefore it is theoretically probable that the weaker showing for the low ability level girls occurred by chance. In such a case, an accumulation of like trends might establish enough evidence of such a trend. It is important that attention be given by educational technologists to the trends in research findings as well as to the significance of differences.

The performance of the high ability level boys and girls in all variations of the program indicate that they can do as well without these program techniques. Therefore, in combining the data of this study it would seem that the program as used is most suitable for low and middle ability levels. A more concise procedure could have been used with the high ability level.

The findings of this study seem to fit into an evolutionary development of research on the techniques involved. The writer feels that the findings complement and add to most of the previous research rather than conflict with it. He feels that the findings relate very closely to Gagne's hierarchical theory of learning but he would like to leave as much latitude as possible concerning the manner in which prerequisite hierarchical levels are attained until we know more about

the roles of mental ordering, insight, confidence, motivation and the need for achievement in learning situations.¹

This study did uncover somewhat of a disagreement with Crist's observation that reasonably homogeneous initial groupings could be made on the basis of aptitude scores.² A casual inspection of raw scores in several of the cells of the matrix in this study shows a tendency for the scores to line up in two divergent groups. This phenomena also contributes to larger standard errors of the mean for some cells than the writer would have preferred. For the kind of learning involved in this study, aptitude does not seem to be the best within cell indicator of final scores. If the subjects in this study could reasonably have been twice instructed from their classes, it is conceivable that a random distribution of the three levels of achievement based specifically on an entry level test could have produced more homogeneous scores in each cell.

Summary

From an experiment that attempted to determine through a series of multiple analyses of variance the effects of sex, of three levels of mental ability and of five variations of a program for the solution of a criterion block design problem, the following

¹Robert M. Gagne, Conditions of Learning. (New York: Holt, Rinehart and Winston, 1965.)

²Robert L. Crist, "Group Use of Programmed Instruction As A Means of Generating Homogeneous Study Groups." A. V. Communications Review, Vol. 17, No. 2, 1963, p. 204.

findings were as follows:

In this kind of learning the technique of sequencing made a difference significant at the .01 level for the middle and low ability level.

The technique of cueing made a difference significant at the .01 level for the low ability level.

There was no significant (.05) differences found between the program and the group paced version of the program.

Plotting of the various comparisons of the means showed a similar trend for all variations of the program with the program itself.

The low ability levels showed the greatest need for sequencing, cueing and individual response. As the ability level rose, the need became less. The high ability levels showed no need for any of the program techniques. The program itself was adequate for all levels except the low ability level of girls where a plotting of the means showed some non-significant decrement and therefore a possible need for enrichment.

These findings are considered to be complimentary and supplementary to the findings of the evolutionary research process that has been going on in these areas.

The special import of the findings of this study for educational technology seems to be that optimum use of the techniques of sequencing, cueing and individual response is most needed when the material to be learned is strange to the learner or when the order of concepts is difficult for the learner to grasp. Also, low

ability students should get priority consideration for programmed instruction. Good programming specifically answering the needs of their learning style and keyed to their entry level should develop significant gains in learning for low ability learners.

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